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SENSITIVITY STUDY OF THE XR-3 LOADS AND MOTIONS COMPUTER PROGRAM SIDEWALL PARAMETERS AND FORCES ON ROLL BEHAVIOR IN CALM SEA AND A COMPARISON TO TESTCRAFT TURN MANEUVER DATA

Rolf-Guenther Riedel

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THESIS

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by

Rolf-Guenther Riedel

June 1977

Thesis Advisor: Alex Gerba, Jr.

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requirements for the degree of

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I. INTRODUCTION

A. Background

In the past several years the Surface Effect Ship (SES) has received increased attention in the United States Navy and detailed investigations of its sea performance have been carried out. The two major categories of SES are the Air Cushion Vehicle (ACV) and the Captured Air Bubble Ship (CAB). The CAB-type of craft has become of primary interest to the United States Navy and two of the constructed testcrafts are the Bell Aerospace Systems 100-B and the XR-3 of approximately 100 and 3 tons of displacement, respectively. In 1976 the U.S. Navy Surface Effect Ship SES 100-B of the CAB-type established a world speed record for surface type ships of 89.4 knots. In April 1976 the SES 100-B launched a missile at 60 knots. The launch was successful and the missile hit its target five miles away.

In order to investigate the characteristics of the CAB-type SES under any design and operating conditions without the costly need of modifying the actual craft, a Loads and Motions digital computer program was developed by Oceanics, Inc. [Ref. 1]. In 1970 the XR-3 testcraft was delivered to the Naval Postgraduate School and Leo and Boncal converted the 100-B Loads and Motions program to represent the XR-3. Since there were substantial design differences between these two ships programming modifications were required in certain subroutines.

B. Objectives

The purpose of this thesis is to investigate one aspect of safe maneuverability of these high speed ships, i.e. their roll behavior in a turn maneuver. To fulfill this objective the sensitivity of the simulated XR-3 roll behavior in turn maneuvers as it is represented by the Loads and Motions Program is investigated for its dependence on changes in sidewall characteristics. The effect of modifications in the added mass computation, sidewall parameters and force calculations as well as propulsion and rudder input parameters are investigated. An evaluation of the computed performance is obtained by comparison with experimentally measured steady state roll conditions.

II. INITIAL REMARKS

A. PROBLEM OF REPEATABILITY

It has been this author's experience as well as all previous investigators at the Naval Postgraduate School using the XR-3 Loads and Motions Program that there have been no observed problems related to repeating the results for a given input condition. However, during the author's first studies of the Loads and Motions Program as listed in Menzel's thesis [Ref. 2] an attempt was made to duplicate some of the simulation runs given in that reference work. It was found necessary as a first step to restore the simulation program on the IBM 360/67 computer from a card source onto a disk.[1] Using the input conditions stated in Ref. 2 it was impossible to obtain identical time histories, e.g. for turns. Each time subroutine SIDEWALL was read into the computer together with the data input deck, thereby overriding the stored program, an error message in the printed output indicated that a division by zero occurred in this subroutine. The error message was not generated when the stored program which contained an identical version of subroutine SIDEWALL was called. A closer look revealed that in the SIDEWALL-version given in Ref. 2 the variable PBAR (plenum pressure) was neither

---

[1] It should also be noted that results obtained in Ref. 2 used the IBM 360/67 Release 20.6 system while the results obtained in this work used the 21.8B Release with HASP installed.

defined nor transferred by a COMMON-statement and therefore a default value of zero was used during the computation of PBHEAD (see Appendix C, SDWL 0440). The missing statement

```
PBAR = PB - PINF
```

was inserted to subroutine SIDEWALL. With this correction the new results were slightly closer to those given in Ref. 2.

The table given below compares output values for roll and pitch angle in a turn at 20 kn with constant thrust and a 35 degrees rudder step input under calm sea conditions.

TABLE I
20 kn turn at 35 deg rudder angle

	without PBAR-card	with PBAR-card	Ref. 2	relative deviation
Roll angle (deg)				
first peak	7.44	7.39	7.2	2.6 %
avrg at 20 sec	2.65	2.77	3.1	11.9 %
Pitch angle (deg)				
first peak	1.34	1.33	1.2	9.8 %
avrg at 20 sec	0.99	0.94	0.8	14.9 %

Although the differences between columns 2 and 3 in TABLE I might be considered to be small as far as magnitudes are concerned , the relative deviation is up to 15 % as shown in column 4. But what is more important is the fact that the roll and pitch angle responses for the uncorrected (plots 1 and 2 in Appendix A) as well as for the corrected program (plots 3 and 4) show an unstable craft behavior for t>40 sec where the pitch angle increases rapidly while the roll angle

decreases rapidly approaching the zero degree value. This unstable condition is probably due to the 35 degrees rudder step input at 20 kn, as it is used in Menzel's study, which is physically unreal since it could never be introduced to the XR-3 testcraft in an actual run at that speed. Therefore rudder angles of up to 15 degrees introduced at a rate of 5 deg/sec will be used throughout this work, as it is also done on the testcraft.

Also, regarding plots 1-4 again and not considering whether they really reflect the actual craft behavior, it should be noted that a short time history ($t<20$ sec in Ref. 2) could possibly result in wrong conclusions because the unstable condition is not evident at that instant of time. Therefore, time histories of up to 40 or 50 seconds will be shown throughout this study.

B. STEADY STATE CONDITIONS

Due to the change in subroutine SIDEWALL as mentioned in the preceding section the steady state conditions for straight runs in calm water have been reestablished for various speeds and are listed in Table II.

Table II
Steady State Conditions

Speed (kn)	Draft (in)	Pitch angle (deg)	Plenum pressure (psf)	Thrust (lb)
10.0	8.17	1.62	23.93	400.61
12.5	7.03	1.11	24.84	349.42
15.0	6.74	0.84	24.84	335.71
17.5	6.41	0.63	24.84	346.45
20.0	6.12	0.48	24.84	373.44
22.5	5.87	0.36	24.84	411.53
25.0	5.66	0.29	24.84	458.62
27.5	5.48	0.25	24.84	513.31
30.0	5.34	0.26	24.84	574.43

These steady state conditions have been established by first executing the XR-3 Loads and Motions Program with constant speed for 40 seconds and then repeating the run keeping the evaluated thrust constant. A comparison of these steady state values with those given in Ref. 2 shows differences especially in the lower and upper speed range of again up to 15 % the cause of which could not be suspected anywhere else since the simulation program has not been changed since last used by Menzel.

C. SIGN CONVENTIONS

The sign conventions used in the XR-3 Loads and Motions Program are identical to those used in Report 71-84 by Oceanics Incorporated [Ref. 1]. A right handed coordinate system is applied to the craft with the positive X-axis being measured forward and the lateral Y-axis being measured positive to starboard. The vertical Z-axis is measured positive downward. Identical signs are used for respective forces along those axes.

The signs of the angles are defined in the following manner :

pitch angle being positive upward
(boat noses up)

roll angle being positive to starboard
(boat rolls to starboard)

yaw angle being positive to starboard
(boat turns to starboard)

rudder angle being positive to port
(right rudder, boat turns to port) .

Zero pitch and roll angle are referenced to the X-Y plane parallel to the water surface.

III. INVESTIGATION OF SIDEWALL EFFECTS

A. ADDED MASS EFFECT

1. Theory

A basic element in representing the hydrodynamic forces by use of slender body theory are the two-dimensional sectional values of lateral added mass A22 of the sidewalls, which are necessary for the determination of the lateral forces, as well as the two-dimensional sectional vertical added mass A33 which is also used in determining the roll moment. These two-dimensional added mass values are given in the 'Surface Effect Ships Aero/Hydrodynamics Technology Design Manual' [Ref. 3] as

$$A22 = C_h * RHO * PI * D * D/2.0$$

and

$$A33 = C_v * RHO * B * B/8.0$$

where C_h is the lateral added mass coefficient

C_v is the vertical added mass coefficient

RHO is the specific density of sea water

D is the local draft

and B is the width at the local sidewall waterline.

The C_h and C_v values originally selected in Ref. 1 were those corresponding to high speed with C_h=0.4 and C_v=1.0. But in order to account for variations in sidewall shape, and their influence on the effective lateral added mass, the results of the research work described in Ref. 3 led to an average value of C_h=0.8. This new coefficient improved the agreement between theoretical and experimental data as stated in Ref. 3 . In the present XR-3 Loads and Motions Program a value of C_h=0.4 is used in accordance with Ref. 1 and the effect of letting C_h=0.8 will be investigated in later parts of this thesis.

Considering the equation for the vertical added mass A33, a major difference has been found between that one given in Ref. 3 and the one used in the XR-3 Loads and Motions Program (e.g. Ref. 2), where in accordance with Ref. 1 (1971) there was an additional PI-factor in the A33s equation. The letter 's' indicates that the computation of the added mass is done at the craft's stern. Since Ref. 3 (1976) reflects the experimental and theoretical work being done based on Ref. 1, the A33s equations in subroutines SIDEWALL and SIDETAB have now been changed to the new form given above.

2. New Steady State Conditions

The change in the simulated XR-3 performance due to the reformulated A33s computation can be observed from TABLE III giving the new steady state conditions for straight runs in calm sea for various speeds which are identical for both (0.4 and 0.8) lateral added mass coefficients.

TABLE III
Steady state conditions
(new A33s)

Speed (kn)	Draft (in)	Pitch angle (deg)	Plenum pressure (psf)	Thrust (lb)
15.0	6.80	0.86	24.84	336.30
17.5	6.46	0.65	24.84	347.23
20.0	6.17	0.49	24.84	374.38
22.5	5.92	0.37	24.84	412.62
25.0	5.71	0.30	24.84	459.90
27.5	5.53	0.27	24.84	514.89
30.0	5.40	0.28	24.84	576.66

Comparing these steady state values with those previously given in TABLE II in Sect. II.B one finds in general for all speeds that

- draft has increased by about 0.05 in (0.8 %)
- pitch angle has increased by 0.02 deg (2 to 7 %)
- thrust has slightly increased by less than 0.5 % .

3. Effect in a Turn maneuver

The effect of the change in the formulation of the vertical added mass in a simulated turn maneuver has been studied next. After a 5 sec straight run at 20 kn in calm sea a port rudder deflection was introduced at a rate of 5 deg/sec and then kept fixed at 15 degrees resulting in a turn to port. The deadrise forces are computed at the transom. In TABLE IV are shown the steady state conditions and the roll moments contributed from the bow seal (FKBS), stern seal (FKSS), sidewalls (FKSW), rudder (FKRUD), propulsion system (FKP), aerodynamics (FKAED) and plenum pressure (ABPB*PHI*Z).

TABLE IV
Steady state conditions in 20 kn turn
15 deg port rudder angle

		old A33s	new A33s	deviation
pitch angle	(deg)	0.48	0.52	8.3 %
roll angle	(deg)	2.0	1.98	- 1.0 %
draft	(in)	5.86	5.94	1.4 %
speed	(kn)	19.25	19.27	0.1 %
moments:				
FKBS		-391.1	-386.3	- 1.2 %
FKSS		- 3.6	- 3.6	0.0 %
FKSW		191.0	202.0	5.8 %
FKRud		- 97.5	-110.0	-12.8 %
FKP		0.2	0.2	0.0 %
FKAed		- 54.4	- 53.5	1.7 %
ABPB*PHI*Z		355.4	351.9	1.0 %

From TABLE IV it can be seen that, due to the modified A33s computation, the counteracting roll moments from the sidewall (FKSW) and rudder (FKRUD) changed by about 6 and 13 %, respectively, resulting in only a little effect in generating a tendency toward a smaller roll angle which is directed out of the turn. Other major contributions to the roll angle are from the bow seal (FKBS directed into the turn) and from the plenum pressure (ABPB*PHI*Z) directed out of the turn. The corresponding plots (plots 5 - 8 for old A33s, plots 9 - 12 for new A33s) show that with the new equation for A33s the pitch and roll angle response curves are less damped than they were using the former equation for vertical added mass calculation as would be expected.

It should be noted that the roll moment due to rudder is fairly large and changes quite significantly while the moment contributed by the propulsion is very small and constant. The cause of this will be investigated in chapter IV.

B. DEADRISE ANGLE

1. Background

Surface Effect Ships (SES) of the captured air bubble type (CAB) have rigid sidewalls immersed into the water, thereby - together with the bow and stern seal - capturing the air in the plenum chamber and reducing air leakage. Since the sidewalls of the XR-3 are not uniform in cross-sectional shape throughout their length but are curved on the outboard side near the bow similar to a single hull ship, the expression "sidehulls" would be more appropriate, as can be found in modern literature.

The importance of the correct understanding of the effect of the sidewalls on the craft's performance is readily seen from a report on SES Research with the XR-1 testcraft [Ref. 5]. As reported, the first test series were carried out successfully with a 45 degrees sidewall deadrise angle, which is the angle between the horizontal plane and the ship's outer sidewall surface. In 1964, after a modification of the craft to 60 degrees deadrise angle and articulating seals, an unstable roll condition occurred during a turn at 35-37 knots, a maneuver performed many times before. The testcraft heeled out of the turn , nosed down due to the retraction of the bow seal, continued its outward roll motion and then flipped over. The report, however, does not mention the rudder action generating the turn. After this accident, the deadrise angle had been changed back to 45 degrees. From this experience the surface effect ship's roll stability should be expected to

be sensitive to the deadrise angle and an investigation of this sensitivity is reported in the following sections.

2. Forces due to Deadrise Angle

The deadrise angle, as pointed out by Ref. 3 and 4, has a major effect on the craft's roll motion and therefore is an important design consideration. During a turn the craft is desired to heel inboard, thereby minimizing the apparent transverse acceleration (a coordinated turn). For typical SES designs, it is not possible to achieve perfect coordination, but it is possible to achieve nearly flat turns if the craft is designed properly. The principal factors affecting roll stability at speed are

* sidewall geometry

* seal characteristics

* vertical location of the center of gravity.

The forces acting at the center of gravity station of the starboard sidewall in a port turn are shown in Figure 1. The centrifugal force generated acts away from the center of the turn. This force must be counteracted by hydrodynamic forces which are created by yawing the ship into the turn. To an observer aboard the craft, it would appear as if the craft is sideslipping. Wave buildup on the outboard sides of the sidewalls increases the pressure there, while only small pressure changes occur on the inboard side of the opposite sidewall generating a small (negligible) vertical force. The principal force arises from the outboard side of the sidewall. The direction of this force depends on the slope of the deadrise angle. If the resultant force passes above the center of gravity (solid line in Fig. 1) a restoring

moment results, tending to heel the craft into the turn thereby improving its roll stability. If the deadrise angle is chosen to be larger (e.g. 70 deg, shown dashed), the resultant force passes below the center of gravity, resulting in a moment tending to heel the craft out of the turn.

Thus, once the SES geometry and the exact vertical location of the center of gravity are known, an approximate check for stability in a turn can be made.

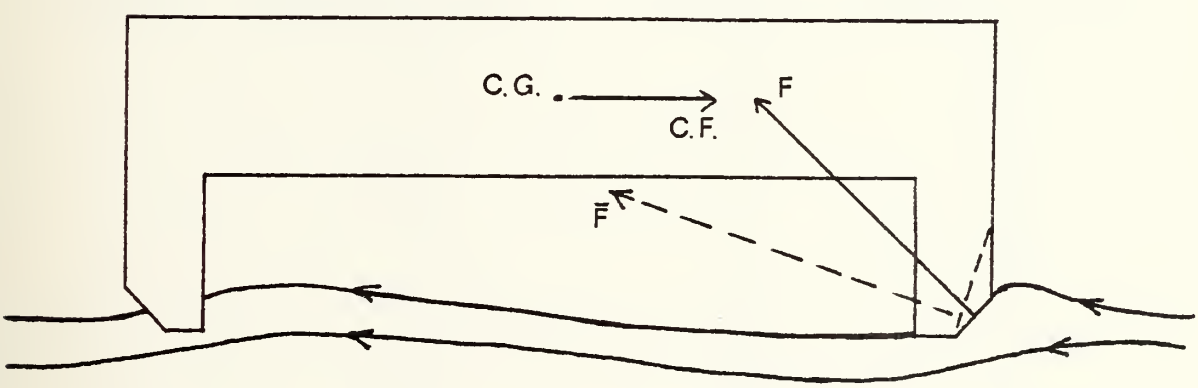


Figure 1 - GENERAL ROLL STABILITY CHECK IN A PORT TURN (C.F. CENTRIFUGAL FORCE, C.G. CENTER OF GRAVITY)

3. XR-3 Sidewall Geometry

From the construction data entered into the sidewall table (subroutine SIDETAB) Figure 2 has been drawn showing the cross sections at several selected stations of the starboard sidewall. Since in most simulation runs (which will be discussed later) draft was less than 7 inches, the deadrise angles for all stations immersing into the water have been calculated by straight line approximation and are given in TABLE V. The stations are counted from bow (station 0) to stern (station 28) and are not equally spaced for station numbers less than 11. The center of gravity has been located experimentally at station 14. The average deadrise angle of all stations listed is 64.3 degrees.

TABLE V

Deadrise angles (deg) for all stations

Straight line approximation for 7'' draft

Station	Deadrise angle	Station	Deadrise angle
5	67.6	17	62.1
6	70.8	18	64.0
7	57.9	19	65.3
8	54.4	20	66.7
9	53.7	21	68.1
10	53.7	22	6.96
11	53.7	23	70.3
12	55.6	24	71.1
13	57.3	25	72.4
14	58.5	26	73.8
15	59.7	27	76.9
16	60.9	28	78.8

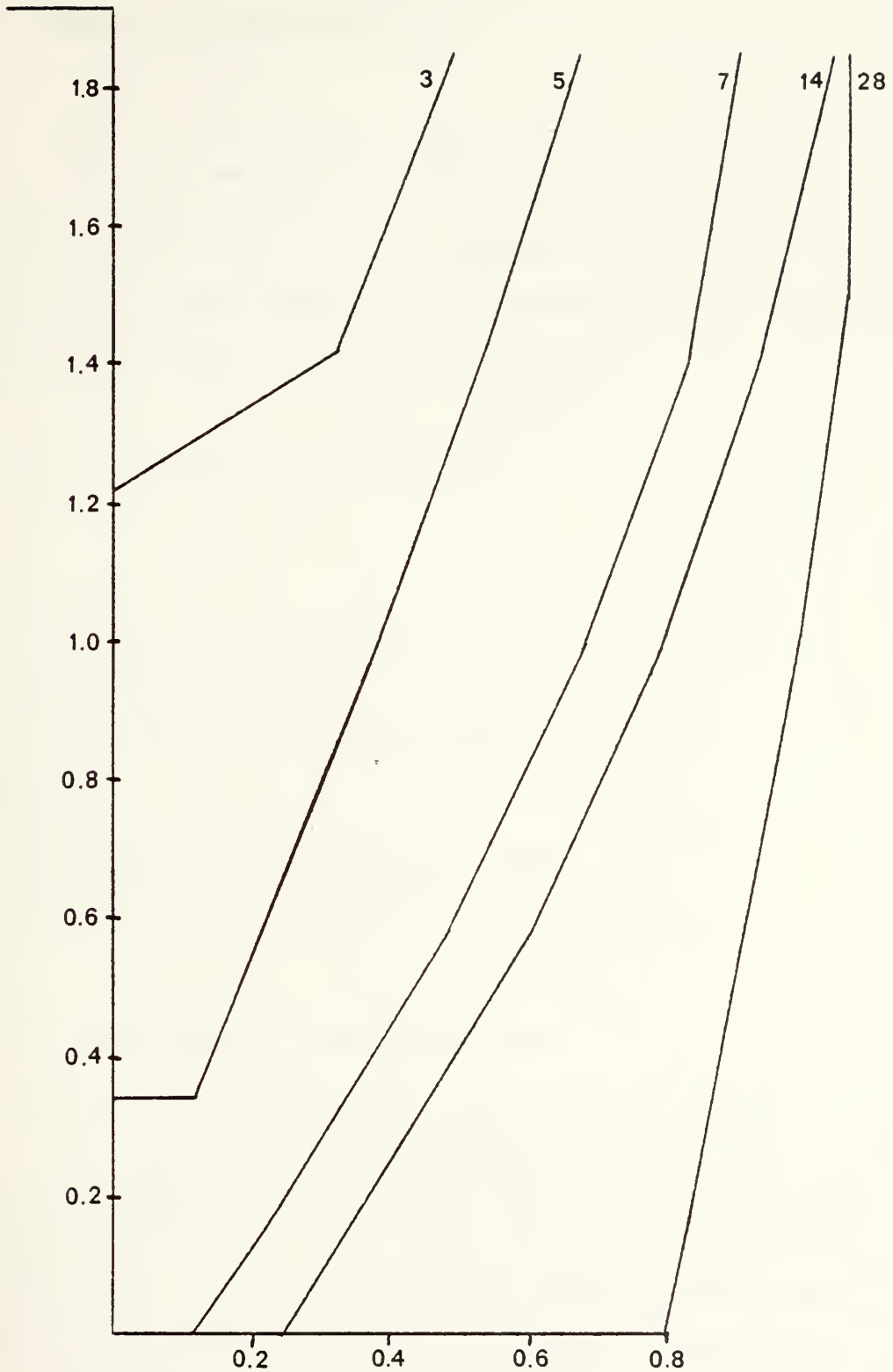


Figure 2 - XR-3 STARBOARD SIDEWALL CROSS SECTIONS
(STATIONS AS INDICATED, UNITS IN FT.)

4. Effect of Deadrise Angle

From the previous discussion the surface effect ship's stability behavior is expected to be sensitive to the sidewalls' deadrise angle. In the XR-3 Loads and Motions Program listed in Ref. 2 the deadrise angle at the transom (78.8 deg) had been used for the computation of the deadrise forces. This calculation was implemented into subroutine SIDEWALL using the following statements:

```
      FYH(J)=-A22S*U*(V+XSS*R-ZS*P)
      •
      •
      CTNDR=0.0
      IF(DSS.LE.0.0) GO TO 22
      CTNDR=(ES-BB(1))/DSS
      IF(THETA.LT.0.0) CTNDR=0.39391
   22 CONTINUE
      FZHOLD(J)=FZH(J)
      FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1
      FZH(J)=FZH(J)+FZHDRP(J)
      •
      •
      FK=(FZH(2)-FZH(1))*YSW+FKD-FY*ZS
```

The projection of the lateral force FYH(J) at each sidewall (J=1 for port, J=2 for starboard side) produced the respective component of vertical force FZH, where FZHDRP is the projected force and CTNDR is the cotangent of the deadrise angle. The roll angle had been already taken into account in the computation of DSS (draft at the stern). The factor PROMO1 simply provided a means to arbitrarily change the vertical projected force for studies undertaken in Ref. 2. The factor PM1 introduced the necessary sign change

in the sidewall force computation being dependent on the craft's side (PM1=-1 for port, PM1=+1 for starboard side). The roll moment FK was partly determined from the vertical forces of both sidewalls.

Comparing the deadrise angles given in TABLE V it is seen that the transom deadrise angle of 78.8 degrees is unique and the largest along each sidewall and no reason could be found why just the transom deadrise angle should be used for the vertical force computation. This fact rather came up when Leo and Boncal (Ref. 8) scaled down the simulation program of the 100-B testcraft to create the XR-3 Loads and Motions Program. For the 100-B testcraft the sidewall cross sections are uniformly shaped throughout most of its length. This uniformity does not occur for the XR-3, as shown in Figure 2. Therefore it has been supposed that another deadrise angle which is more representative for all angles existing along the XR-3 sidewalls, e.g. the deadrise angle at the center of gravity location (station 14), could possibly be more appropriate for the vertical force computation. To investigate the effect of this supposition, turn maneuvers in calm sea at 20 knots and various rudder angles have been simulated for both deadrise angles and lateral added mass coefficients.

TABLE VI

Steady State Roll Angle (deg) at 20 kn for various Rudder Angles (deg)

Rudder angle	Deadrise force computation at transom	center of gravity		Experimental testcraft data (Ref.6)
	C_h=0.4	C_h=0.4	C_h=0.8	
5	0.52	0.32	0.29	0.09
9	1.07	0.78	0.72	0.28
12	1.50	1.15	1.11	0.58
15	1.98	1.53	unstable	1.36

Table VI shows the steady state values for the roll angle which are compared with those measured experimentally in 1974 and documented in Ref. 6. Since the XR-3 Loads and Motions Program under investigation represents the XR-3 craft configuration as it existed in 1974, Ref. 6 may serve to check whether the results produced by certain changes in the simulation program are favorable or not. It is not anticipated to exactly match the results obtained from the simulated runs to the measured values since for the testcraft data the following precisions for the measuring devices are stated in Ref. 6 : pitch and roll angle ±0.5°, rudder angle ±1.0° and speed ±1 kn. From TABLE VI it is obvious that the steady state values for roll angle using C_h=0.4 as the lateral added mass coefficient and the center of gravity deadrise angle for the vertical force computation are closer by 25 to 40 % to the measured angles than are the corresponding roll angles considering the transom deadrise angle.

Using the center of gravity deadrise angle and the lateral added mass coefficient C_h=0.8 as suggested in Ref. 3, the agreement in steady state roll angles could be improved by another 3 to 10 % for rudder angles up to 12 degrees. This improvement has also been reported in Ref. 3. Comparing the roll angle responses for turns generated by a 12 degrees rudder angle to port with C_h=0.4 (plots 21 and 22) and C_h=0.8 (plots 23 and 24) it is found that the smaller lateral added mass coefficient generates a little higher peak roll angle (1.47°) than does the larger coefficient (1.27°). Both responses show the same number of oscillations (eleven cycles) until they die out. The larger lateral added mass coefficient generates a small negative

roll angle shortly after the port rudder motion has been introduced. However, for a 15 degrees port rudder angle the simulation program showed an unstable response with increasing amplitudes of oscillation for pitch and roll angle (see plots 17 and 18). From this the lateral added mass coefficient being 0.8 does not seem to be appropriate for the XR-3 simulation if both sidewalls are considered for the vertical deadrise force computation. The effect of using both lateral added mass coefficients will be considered again in Sections III.D and E.

From TABLE VII it can be seen that the roll moments contributed by the bow seal (FKBS), plenum pressure (ABPB*PHI*Z), rudder (FKRUD) and sidewalls (FKSW) change the most. Comparing the effect due to the change from transom to center of gravity deadrise angle it is found that

- bow seal inward effect decreases

- plenum pressure outward effect decreases

- rudder inward effect decreases

- sidewall outward effect increases

= outward roll angle decreases.

The time histories for simulated turn maneuvers with 15 degrees port rudder angle using center of gravity and transom deadrise angle (TABLE VII) are shown in Appendix A as plots 13-16 and 9-12, respectively. Comparing these plots the effect of the change from transom to center of gravity deadrise angle and C_h=0.4 can be observed as

- pitch angle response being more damped

- roll angle response being more damped

- pitch and roll rate responses being more damped and having smaller peak values.

TABLE VII

Steady State Values for selected Deadrise Angles
20 kn Turn, calm Sea, 15 deg port rudder angle

Deadrise Angle	Transom	C. of G.	arbitrarily chosen	
(degrees)	78.8	58.5	31.6	28.7
Pitch angle (deg)	0.52	0.45	0.52	0.64**
Roll angle (deg)	1.98	1.53	0.31*	- 0.33*
Draft (in)	5.94	5.81	6.07	6.52
Speed (kn)	19.27	19.37	19.1	18.7
FYSW	-824.0	-821.9	-810.0	-801.0
FYRUD	40.0	32.7	39.5	55.8
FYAED	- 19.5	- 20.0	- 19.1	- 17.6
R*V*AM	803.5	809.2	789.6	762.8
FKBS	-386.3	-336.4	- 68.4	71.6
FKSS	- 3.6	- 2.7	- 0.5	0.5
FKSW	202.0	212.1	175.0	184.0
FKRUD	-110.0	- 89.9	-108.4	-153.0
FKAED	- 53.5	- 56.0	- 52.4	- 46.2
FKP	0.19	0.14	0.03	- 0.03
ABPB*PHI*Z	351.9	273.5	54.6	- 57.2
FYH (P/S)	-39/-147	-45/-126	-78/-95	-107/-88
FYD	-637.8	-651.4	-637.3	-607.0

Note : * = still decreasing
** = still increasing, not quite steady state

The reason for the sidewall roll moment and thereby the net roll effect not changing more pronounced (TABLE VII) is that not only the lateral force FYH must be considered in order to determine the force F effecting roll stability (Sect. III.B.2, Fig. 1) but also the lateral drag force FYD has to be taken into account. Considering the XR-3 geometry using the center of gravity deadrise angle, as it is shown in solid lines in Fig. 3, the lateral force FYH can be seen to generate the vertical projected force FZHDRP and the force F, which is directed well above the center of gravity. But since FYD has to be added vectorially to the force F and its strength being several times larger than FYH (TABLE VII) the new resultant force F' determining the craft's roll behavior is directed well below the center of gravity (although F being directed above it). Thereby an outward roll angle is generated.

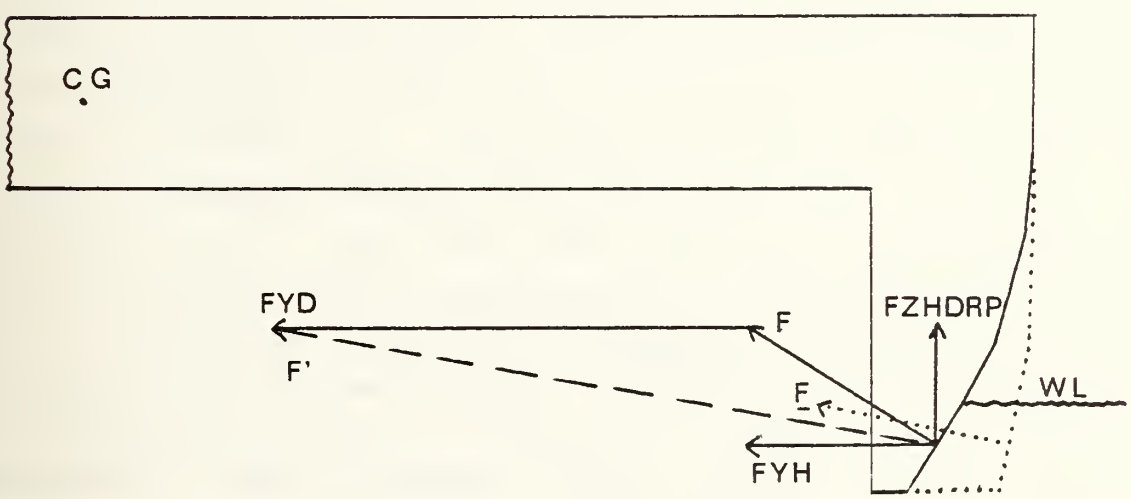


Figure 3 - DEADRISE AND DRAG FORCES IN A PORT TURN
(CG= CENTER OF GRAVITY, WL= WATER LINE)

Also from Fig. 3 the effect of considering the center of gravity versus the transom deadrise angle on the force generating the inward or outward roll moment can be seen. The center of gravity deadrise angle and its corresponding forces are shown in solid or dashed lines with F being directed above the center of gravity. The transom deadrise angle, shown in dotted lines, generates a force F being directed below the center of gravity producing an outward roll moment which gets reinforced by adding vectorially FYD. From this the general stability check yields a smaller outward roll moment and angle using the center of gravity versus the transom deadrise angle. This is in agreement with the results given in TABLE VI.

Next, some simulation runs with arbitrary deadrise angles chosen such that small positive and negative steady state roll angles result are presented in order to, first, find out which deadrise angle would generate the moments necessary to simulate flat turns, and, second, verify the trend of the change in the respective moments which has been observed for the change from transom to center of gravity deadrise angle in TABLE VII. The value of the lateral added mass coefficient in these runs was 0.4 as it was in all runs listed in TABLE VII. Considering the roll moments over the range of deadrise angles from 78.8 to 28.7 degrees, the moments due to the bow seal, stern seal, propulsion and plenum pressure change consistantly in magnitude while those due to sidewalls, rudder and aerodynamics reach some extreme value and then increase again. Regarding the steady state roll angles listed in TABLE VII, it can be seen that the arbitrary chosen deadrise angles happen to be nearly symmetric about the deadrise angle that would generate zero roll angle (flat turn) under these simulation conditions. Keeping this symmetry in mind one finds that the values of the roll moments due to bow seal (FKBS), stern seal (FKSS), propulsion (FKP) and plenum pressure (ABPB*PHI*Z) are also

symmetric with respect to zero moments. For propulsion and plenum pressure the sign of the moments are identical to that of the roll angle while for bow and stern seal moments the signs are reverse. From the results given in TABLE VII with positive steady state roll angles Figure 4 has been drawn where the dotted line represents the craft's initial state, the dashed line represents the craft's steady state considering the transom deadrise angle and the solid line represents the craft's steady state (smaller roll angle) considering the center of gravity deadrise angle for the vertical force calculation. Same markings apply to the moment vectors shown from which their change in magnitude for both deadrise angles can be seen.

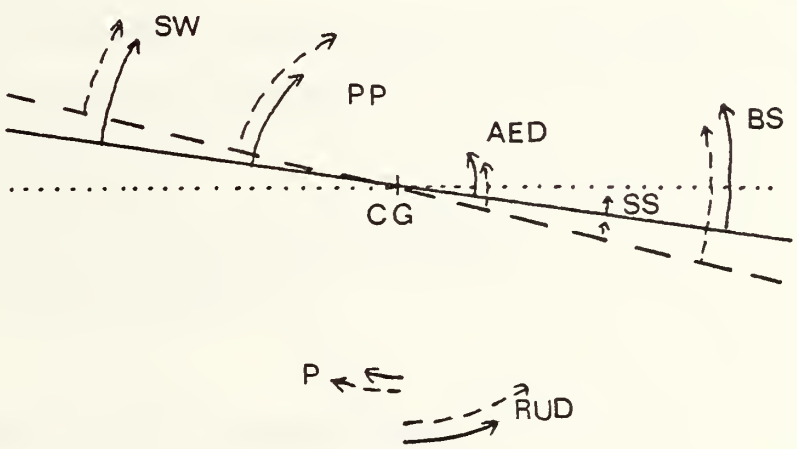


Figure 4 - ROLL MOMENTS IN A PORT TURN
(ROLL MOMENTS AND ANGLE NOT TO SCALE)

Legend:

AED Aerodynamic	CG Center of gravity
BS Bowseal	PP Plenum pressure
SS Sternseal	SW Sidewalls
RUD Rudder	P Propulsion
Deadrise angle: - - -	Transom
———	Center of gravity

Since the simulation run with the center of gravity deadrise angle being used for the vertical force computation gave results that were more favorable (better damped time histories and steady state values closer to those measured experimentally) this change in vertical force computation was implemented into the XR-3 Loads and Motion Program. Starting with the deadrise angle given in Table V for draft up to seven inches, again straight line approximations for the effective deadrise angle at the center of gravity location (station 14) for larger drafts have been performed resulting in an almost linear relationship. This part of subroutine SIDEWALL is now valid for any draft and contains the following statements which have been used in this form for all simulation runs to follow in this study:

```
DDRANG=0.0
IF (DS.GT.0.5833) DDRANG=(DS-0.5833)*0.0629
DRANG=1.021+DDRANG-PM1*PHI
CTNDR=COTAN(DRANG)
FZHOLD(J)=FZH(J)
FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1
FZH(J)=FZH(J)+FZHDRP(J)
•
•
FK=(FZH(2)-FZH(1))*YSW+FKD-FY*ZS
```

It should be noted that vertical projected forces from <u>both</u> sidewalls are used in computing the roll moments in the XR-3 Loads and Motions Program. Section III.E of this thesis will be concerned with the effect of changing the simulation program to consider the deadrise projected force only from the outward sidewall in a turn maneuver as it is discussed in Sect. III.B.2 .

C. CROSS-FLOW DRAG

In the preceding section the lateral force FYD which is due to cross-flow drag has been found to be rather large compared to FYH, thereby changing the direction of the resultant force significantly. FYD is computed in subroutine SIDEWALL by summing the contributions DF of all stations:

```
DF(I,J) = -HRHO*CDSW*VREL*ABS(VREL)*DSWAV(I,J)
```

where DF(I,J) is the lateral drag contributed by the j-th element of each (i-th) sidewall

HRHO is RHO/2.

VREL is relative velocity

DELX is the incremental distance used for the wetted draft calculation along each sidewall

DSWAV is the average wetted draft over one incremental distance

CDSW is the cross-flow drag coefficient for one sidewall .

The cross-flow drag coefficient being used in the present XR-3 Loads and Motions Program is the value corresponding to that for flow normal to a long flat plate being CDSW=1.28 . Ref. 3 points out that an investigation of cross-flow drag forces and coefficients (before the vertical added mass A33 had been reformulated as discussed in Sect. III.A.1) showed better agreement between theoretical and experimental results if CDSW=2.0, representing the normal drag coefficient for a sharp flat plate, had been used instead. After the reformulation of A33 the agreement between modified theory and experiment had very much improved, so

that the former drag coefficient could be used again. Since in this thesis work the change in A33s did not effect the roll behavior significantly (TABLE IV), some turn maneuvers at 20 kn and 15 degrees rudder angle have been simulated for various drag coefficients in order to investigate which CDSW would better match simulated and experimental steady state roll angle. From TABLE VII a decrease in roll angle and roll moment is desireable and therefore the cross-flow drag force FYD should be decreased via reducing CDSW. The steady state values are shown in TABLE VIII with the lateral added mass coefficient being unchanged C_h=0.4.

TABLE VIII

Steady state conditions for various CDSW

20 kn turn, 15 deg port rudder angle

CDSW	1.28	1.16	1.0	0.7
Pitch angle	0.43	0.43	0.44	0.46
Roll angle	1.55	1.48	1.38	1.14
Draft	5.78	5.80	5.83	5.91
Speed	19.39	19.36	19.31	19.19
FKBS	-343.0	-330.5	-308.1	-252.8
FKSS	- 2.7	- 2.6	- 2.4	- 2.0
FKSW	207.8	175.0	127.8	40.0
FKRUD	- 82.2	- 47.9	- 2.3	80.4
FKAED	- 56.6	- 58.7	- 61.6	- 67.6
FKP	0.14	0.14	0.13	0.11
ABPB*PHI*Z	276.4	264.6	246.5	201.9
FYH (P,S)	-43/-125	-45/-125	-48/-124	-57/-121
FYD	-654.9	-616.9	-561.0	-436.0

Comparison with Ref. 6 (Table VI) shows close agreement in roll angle (1.36°) for the run with CDSW=1.0 . But these

trial runs have been executed with arbitrary smaller drag coefficients because an increase in drag coefficient (e.g. CDSW=2.0 for sharp flat plate as in Ref. 3) would have enlarged the disagreement between simulated and experimental data. Also, from plot 29 for CDSW=1.28 and plot 31 for CDSW=1.16 it is seen that a smaller drag coefficient results in more damping in the roll response, in this case six versus nine cycles of distinguishable oscillations. Since the choice of CDSW=1.0 cannot be declared to be appropriate for the actual shape of the XR-3 sidewalls it will not be considered any further in this study. CDSW=1.16 generated a 4 % change (about 15 % is desired) toward the experimentally measured roll angle and its effect will be investigated together with the present cross-flow drag coefficient CDSW=1.28 in the studies to follow.

Shown below in Figure 5 is the dependence of steady state roll angle in turns generated by a 15 degrees rudder angle to port at 20 kn on the cross-flow drag coefficients used in the simulation runs (TABLE VIII).

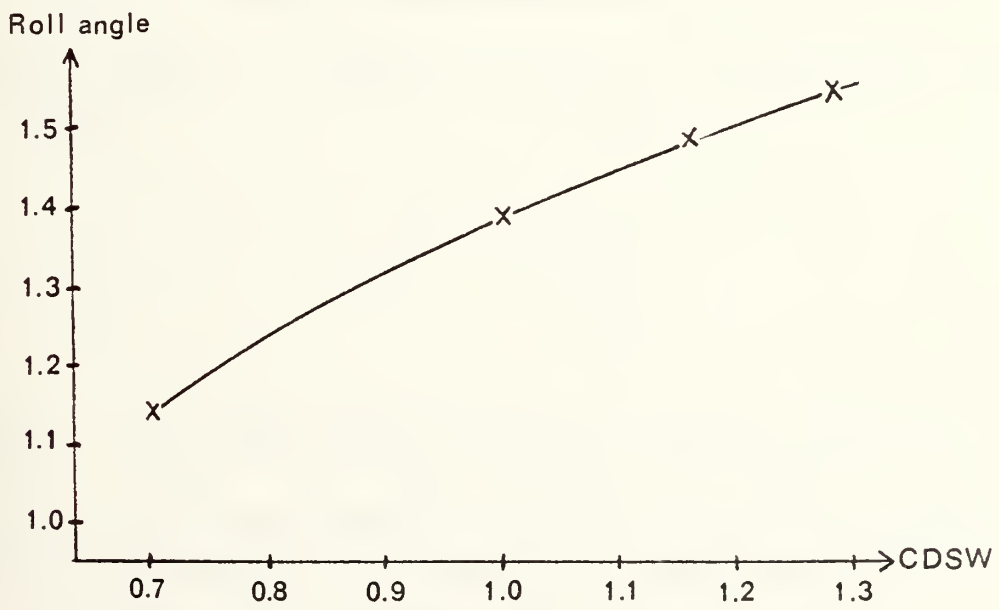


Figure 5 - S.S. ROLL ANGLE VERSUS CDSW

D. THRUST MAPPING

In turn maneuvers as they have been discussed in the preceding sections another important point to be considered is the change in thrust on both engines. Since the engines mounted on the XR-3 provide constant power for a given throttle setting, the actual thrust delivered during a turn maneuver may vary even though the throttle remains fixed. In all simulation runs shown in this thesis until now constant thrust has been used. In Ref. 6 experimentally measured reduction in thrust is given for turn maneuvers at 20 kn and various rudder angles. From this and Ref. 7 providing more detailed information the thrust-rudder dependence was as listed below.

TABLE IX
Reduction in thrust for various rudder angles in turn maneuvers at 20 kn

Rudder angle (deg)	total reduction in thrust (Ref. 6) (%)
5	- 2.8
9	- 3.3
12	- 4.3

TABLE IX has been used for thrust mapping (Block 16 of the data input) in the simulation runs. Due to unavailability of more precise data it has been assumed that the total reduction in thrust is contributed from both engines in equal amounts. But this may not be quite true, since due to the craft's roll angle a difference in immersion depth for both engines could result in unequal

changes in thrust. TABLE X shows the steady state values of these simulations considering two cross-flow drag coefficients, deadrise force contributions from both sidewalls computed at the center of gravity as well as both lateral added mass coefficients C_h=0.4 (0.8).

TABLE X

Steady state conditions using thrust mapping in 20 kn turns at various rudder angles

Rudder angle (deg)	Roll angle (deg) simulation	Ref. 6	Speed (kn) simulation	Ref. 6
CDSW=1.28				
5	0.30(0.25)	0.09	19.3(19.2)	19.8
9	0.71(0.61)	0.28	18.9(19.0)	19.5
12	0.99(0.89)	0.58	18.5(18.6)	19.2
CDSW=1.16				
5	0.28(0.23)	0.09	19.2(19.2)	19.8
9	0.67(0.57)	0.28	18.9(19.0)	19.5
12	0.94(0.84)	0.58	18.4(18.6)	19.2

Comparing the steady state roll angles obtained if thrust mapping is used with those listed in TABLE VI (no thrust mapping, deadrise force computation at the center of gravity), a change in roll angle by 6 to 14 % for C_h=0.4 and by 14 to 20 % for C_h=0.8 toward the measured angle can be observed. The steady state roll angles found in the simulation runs still differ from the roll angles given in Ref. 6 by a factor of about two and three but can be expected to be a little closer to these if proper thrust mapping, i.e. different maps for port and starboard engine, is used. By this also the steady state velocities which

differ by about 2.5 % can be expected to come in better agreement, i.e. to increase for smaller roll angles.

Regarding the roll angle time responses for simulation runs using both lateral added mass coefficients (0.4 and 0.8) and 12 degrees rudder angle the following characteristics have been found: the runs using thrust mapping (Table X, plot 33(35)) show almost the same transient behavior as do the runs without thrust mapping (Table VI, plot 21(23)) with about ten cycles of oscillation before the transients die out. But the runs using thrust mapping need quite a long time (t>45 sec) before they reach the steady state roll angle.

The effect of using a larger lateral added mass coefficient (0.8) can be observed in plot 35. Comparing this with plot 33, the roll angle response in plot 35 shows a smaller peak roll angle (1.25° versus 1.47°) and the transients have smaller amplitudes. But both die out after ten cycles. This effect has already been noted in Section III.B.4.

Investigating the effect of changing the coefficient CDSW=1.28 to 1.16 by comparison of the roll responses shown in plots 33 and 37 or 35 and 39, a significant damping effect as has been found previously in Section III.C can not be observed here.

E. DEADRISE FORCE OF OUTWARD SIDEWALL

This part of the investigation on how to effect the roll behavior of the testcraft simulation is again concerned with the deadrise angle.

In the present XR-3 Loads and Motions Program deadrise forces for both sidewalls are computed with the deadrise angle appropriately corrected by the roll angle for port and starboard sidewalls. The idea behind this, e.g. in a port turn, is to consider a pressure buildup (large FYH(S)) on the outboard side of the starboard sidewall and a reduction in pressure on the outboard side of the port sidewall (small FYH(P)). Thereby an upward vertical force FZHDRP (with negative sign) is obtained for starboard side, while a downward vertical force (positive sign) is computed for port side. Both vertical forces are then added to the buoyancy force of their side. The forces obtained by this approach are shown in Figure 6.

In Ref. 4, however, a different philosophy in regarding the acting forces is presented. As discussed in Section III.B.2 an approximate check on the craft's roll stability can be made if the SES geometry and the vertical location of its center of gravity are known (Fig. 1). In a port turn the principal force effecting the roll behavior arises from the <u>outboard</u> side of the starboard sidewall (relative high pressure on the structure there due to wave buildup) while there is only a small force (due to small pressure change) on the <u>inboard</u> side of the port sidewall contributing a roll moment only if there exists a roll angle. Now both vertical forces are directed upward. This approach and the resulting forces are shown in Figure 7.

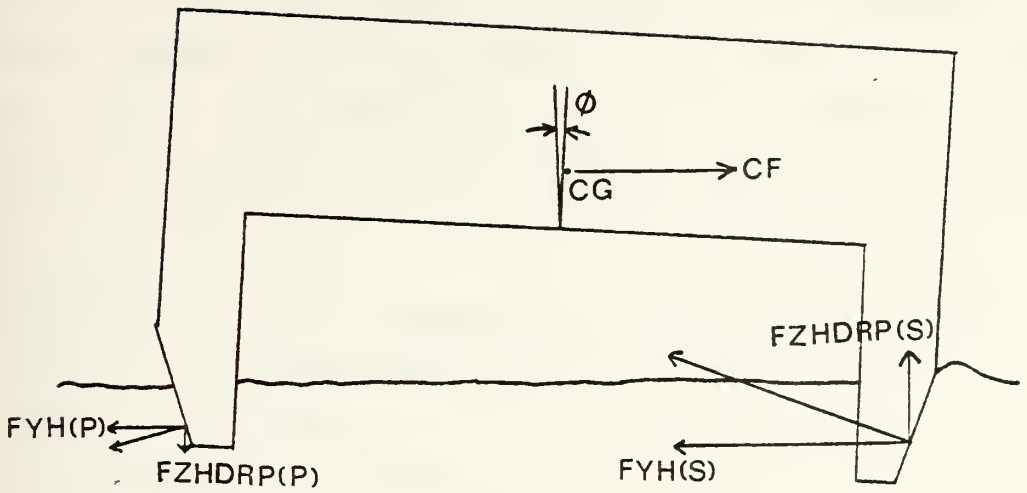


Figure 6 - ACTING DEADRISE FORCES (TWO SIDEWALLS)

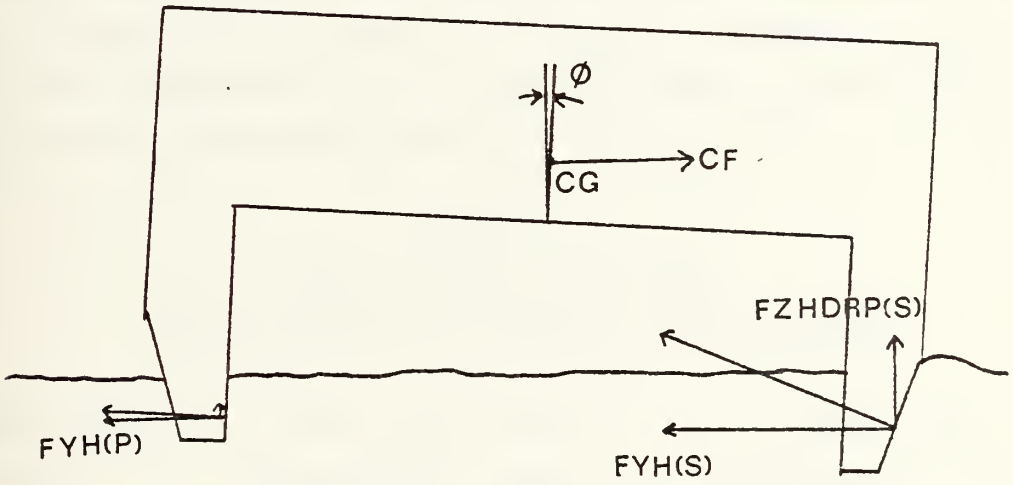


Figure 7 - ACTING DEADRISE FORCES (ONE SIDEWALL)

Note : Since the vertical force contributed by the inboard sidewall is rather small, as shown above, it can be neglected in the roll stability check (Sect. III.B.2).

To investigate the effect of this interpretation of the acting forces two statements controlling the computation of deadrise forces via the sign of the rudder angle RUDANG (port rudder is positive) and the sidewall under investigation (PM1=-1 for port side) have been added to the computation procedure for the vertical projected force :

```
DDRANG=0.0
IF (DS.GT.0.5833) DDRANG=(DS-0.5833)*0.0629
DRANG=1.021+DDRANG-PM1*PHI
CTNDR=COTAN(DRANG)
RUDSIG=SIGN(1.,RUDANG)
IF(RUDSIG.NE.PM1) CTNDR=PM1*TAN(PHI)
FZHOLD(J)=FZH(J)
FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1
FZH(J)=FZH(J)+FZHDRP(J)
```

The steady state values for simulated turn maneuvers using thrust mapping and center of gravity deadrise angle are shown below considering two cross-flow drag coefficients and both lateral added mass coefficients C_h=0.4 (0.8).

TABLE XI

Steady state conditions
in 20 kn turns at various rudder angles

Rudder angle (deg)	Roll angle (deg) simulation	Ref. 6	Speed (kn) simulation	Ref. 6
CDSW=1.28				
5	0.43(0.52)	0.09	19.4(19.5)	19.8
9	0.90(1.00)	0.28	19.1(19.4)	19.5
12	1.22(1.34)	0.61	18.7(19.0)	19.2
CDSW=1.16				
5	0.41(0.51)	0.09	19.3(19.5)	19.8
9	0.87(0.98)	0.28	19.1(19.3)	19.5
12	1.17(1.30)	0.61	18.6(19.0)	19.2

Comparing the steady state values for simulated runs in tables X and XI , the effect of using only the outward sidewall for the deadrise force computation can be observed to give less favorable (little larger) steady state roll angles but more favorable (larger) steady state velocities. This is exactly what has been expected since, as shown in Figures 6 and 7, if deadrise force contributions from both sidewalls are used, the deadrise force from the port sidewall will reinforce the one from the starboard sidewall toward a less outward roll moment (Fig. 6) while applying the philosophy depicted in Fig. 7 the vertical force from the port sidewall counteracts the starboard deadrise force.

Regarding the roll angle responses shown in Appendix A for 12 degrees rudder angle with CDSW=1.28 (plots 41 and 43) and CDSW=1.16 (plots 45 and 47) and comparing these with the corresponding ones from the previous section (plot 33, 35 and 37, 39) the change in the vertical force computation considering the outward sidewall only is seen to result in about 8 versus 10 cycles of transient oscillations with less amplitude. Using C_h=0.8 (plots 43 and 47) has a quite significant damping effect and makes the roll angle response more resemble a step, which is in accordance with the experience gained by Ref. 7. Also, comparing these plots with plots 35 and 39, the negative roll angle occurring at the moment when the rudder has been introduced does not show up any more.

F. VERTICAL LOCATION OF CENTER OF GRAVITY

In Section III.B.2 it was discussed how to check for the testcraft's roll bahavior in a turn provided the SES geometry and the location of the center of gravity are known. This section will be concerned with the effect of different vertical locations of the center of gravity on the simulated XR-3 roll behavior

From experimental measurement the location of the center of gravity of the XR-3 has been determined to be 10.05 ft forward of the transom and Leo and Boncal established the vertical location at 2.54 ft above the keel on the longitudinal center line of the craft. As modifications to the testcraft were introduced (e.g. engines and seals) the horizontal location of the center of gravity was again established experimentally. No such changes were made on the vertical location. In order to investigate the sensitivity of the steady state roll angle to vertical locations of the center of gravity, reductions in height (in accordance with the stability check geometry depicted in Figure 1) in increments of 0.1 ft were entered into the Loads and Motion Program.

Simulation runs with constant thrust and initial speed of 20 kn introducing a 15 degrees port rudder angle, deadrise force contributions from both sidewalls computed at the center of gravity, the sidewall drag coefficient CDSW=1.28 and the lateral added mass coefficient being 0.4 were executed and the results are shown in Table XII. From the listed data it follows that with a lower vertical location of the center of gravity a tendency toward an inward roll angle (here actually a smaller outward roll

angle) can be achieved. As shown, a decrease in vertical distance by 0.1 ft resulted in about 0.1 degree decrease for both peak and steady state roll angle (almost linearly related). From the corresponding plots as indicated in Table XII a roll damping effect due to the relocation of the center of gravity can hardly be recognized. The number of cycles of transient oscillations and the steady state speed were about the same for all runs listed in Table XII.

TABLE XII

Roll conditions in 20 kn turn with constant thrust and 15 degrees port rudder angle

	vertical location of CG				experimental
	2.54	2.44	2.34	2.24	testcraft data
steady state roll angle	1.55	1.43	1.32	1.22	1.36
peak roll angle	1.67	1.53	1.46	1.35	
peak roll rate	2.13	2.07	1.98	1.91	
cycles of transients	8	8	8	8	
refer to plots	13-14	49-50	51-52	53-54	
steady state speed	19.4	19.3	19.3	19.3	18.7

Table XIII shows the effect of changing the vertical location of the center of gravity for simulation runs at 20 kn with 12 degrees port rudder angle and thrust mapping applied, deadrise force computation for both sidewalls at the center of gravity and the coefficients being 0.4 for the lateral added mass and CDSW=1.28 for the sidewall drag. These conditions were similar to those used in Table X.

From Table XIII the effect of reducing the vertical location of the center of gravity in 0.1 ft increments over a reasonable range can be observed to also result in linear reductions in maximum and steady state roll angle for the case if thrust mapping is used. Nonlinear reductions appear for the peak roll rate. The number of cycles during the transient period (ten) is again not effected by the vertical relocation of the center of gravity. Regarding the corresponding plots a very slight damping effect can be observed for reduced vertical locations. The results given in Table XIII are graphically represented in Figure 8 .

TABLE XIII

Roll conditions in 20 kn turn with thrust mapping and 12 degrees port rudder angle

	vertical location of CG				experimental
	2.54	2.44	2.34	2.24	testcraft data
steady state roll angle	0.99	0.91	0.84	0.77	0.58
peak roll angle	1.47	1.36	1.25	1.16	
peak roll rate	2.14	1.92	1.74	1.58	
cycles of transients	10	10	10	10	
refer to plots	33-34	55-56	57-58	59-60	
steady state speed	18.5	18.4	18.4	18.4	19.2

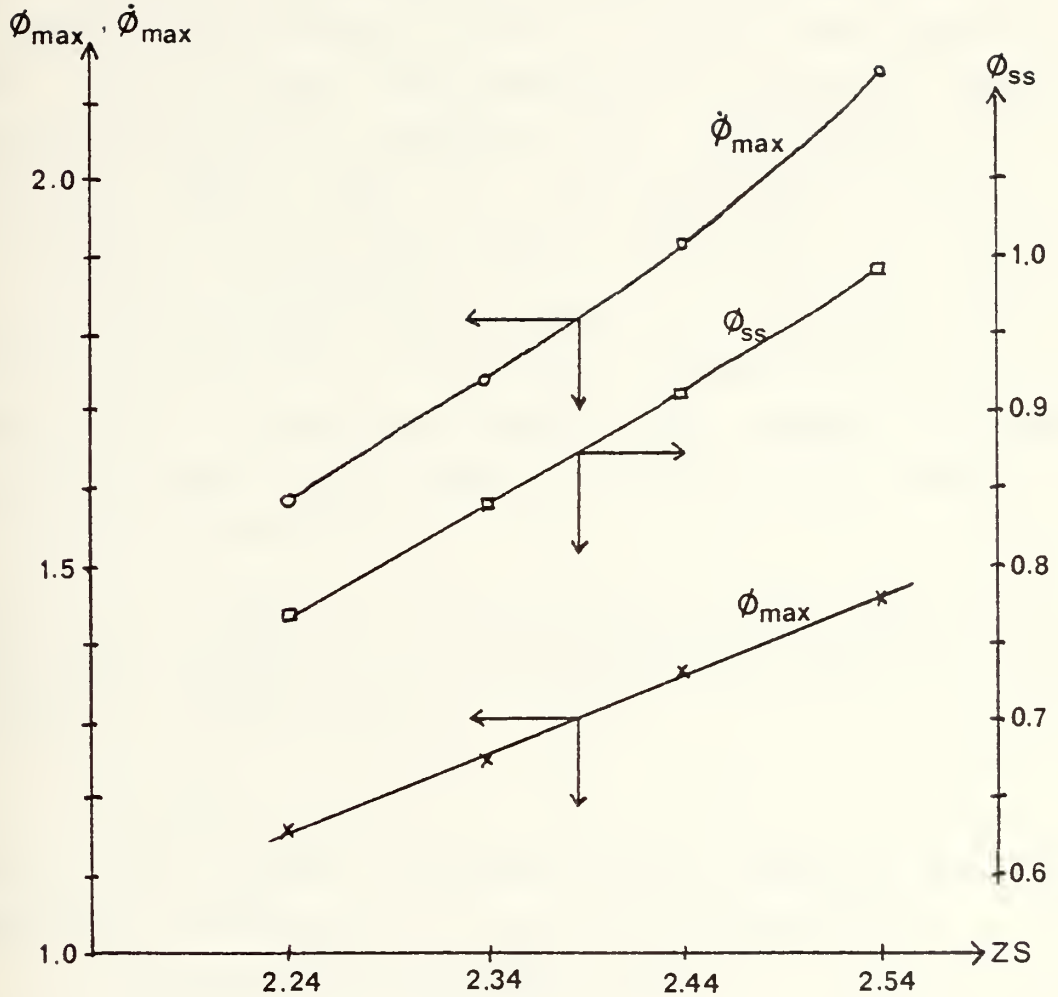


Figure 8 - ROLL CONDITIONS VERSUS VERTICAL LOCATION OF CENTER OF GRAVITY (TABLE XIII)

G. ROLL DAMPING DUE TO VERTICAL WAVE GENERATION

One part of subroutine SIDEWALL is concerned with the roll damping effect which is due to vertical wave generation during a roll motion. The computation of the roll damping term was developed by Oceanics Inc. and added to the program by Menzel [Ref. 2]. The principles used in the development of this addition were not provided by Oceanics Inc., however, the apparent idea is to reduce the computed roll moment FK by some value which is dependent on the craft's roll rate and its draft, thereby on the vertical added mass A33. During the study of the effect of these additional terms a discrepancy was noted in the dimensions used in the calculations.

The roll moment FK is calculated by the equation given in SDWL1950 and considering the expressions leading to this statement it is found that

dim [FK] = lb . ft

which is the correct dimension for a moment vector. Now considering the dimension of the roll damping term

dim [PROMO2*YSW*YSW*BC2*P/PI]

which is subtracted from FK (SDWL2200) it is found

PRCMO2 and PI are dimensionless
dim [YSW] = ft
dim [P] = rad/sec
dim [BC2] = dim [AC2]
= dim [FC2 * length]
= dim [F2 * cos(x) * length]
= dim [A33 * length]

$$= \text{dim}\,[\text{RHO} * B * B * \text{length}]$$
$$= (\text{lb} \cdot \text{sec}^2/\text{ft}^4) \cdot \text{ft} \cdot \text{ft} \cdot \text{ft} \cdot$$

So for the roll damping term

$$\text{dim}\,[\text{YSW} * \text{YSW} * P * \text{BC2}]$$
$$= \text{ft}^2 \cdot (\text{rad/sec}) \cdot (\text{lb} \cdot \text{sec}^2/\text{ft}^4) \cdot \text{ft}^3$$
$$= \text{lb} \cdot \text{ft} \cdot \text{sec}$$

which is not the correct dimension for a moment expression. Assuming that only the given terms may be involved in the roll damping calculation, it is possible to come up with the proper dimension if the roll rate P were squared but keeping its sign, thus getting

roll damping term = PROMO2*YSW*YSW*BC2*P*ABS(P)/PI .

Also the vertical added mass should be associated with some 'velocity squared' - expression which is absent in the original version of this part of the program but could be generated by squaring the roll rate P. The effect of the modified expression will be an increase in the damping effect for roll rates P>1.0 which exist only in the initial phase of the turn maneuver (maximum roll rate in all simulation runs was about 2.0) . But for most of the run length P is less than unity and the supposed modification will decrease the damping effect especially when approaching steady state (P=0.0) .

The PROMO2 - term provides a means to arbitrarily set a roll damping factor which, as stated in Reference 2, has been found from experiments to be 16.0 . Until now PROMO2=1.0 has been used in this thesis work. So the effect of changing it to the experimental value is investigated next. In the runs to be discussed turn maneuvers at 20 kn with a 12 degrees port rudder angle have been simulated with deadrise forces being computed at the center of gravity, using the experimental damping factor PROMO2=16.0 and the

coefficients CDSW=1.28 for the sidewall drag and C_h=0.4 for the lateral added mass.

1. Thrust is held constant with deadrise force contributions from both sidewalls

Comparing the obtained plots 61-62 with plots 21-22 (PROMO2=1.0) only a slight damping effect on roll angle response can be observed (peak roll angle 1.45° versus 1.47°), but the number of transient oscillations decreases from eleven to nine. The peak roll rate decreased from 2.14 to 2.10 for PROMO2=16.0 and the damping effect is more pronounced in the roll rate time history.

2. Thrust is mapped with deadrise force contributions from both sidewalls

Comparing the plots 63-64 with the corresponding ones (33-34) for PROMO2=1.0 , again only a slight damping effect can be noticed. The peak roll angle is again reduced from 1.47 to 1.45° and the number of cycles of transient oscillations is uneffected.

If the damping term is changed to include the P*ABS(P) expression (plots 65-66) there result eleven versus nine cycles of transient oscillations with little higher amplitudes (peak roll angle is again 1.47° as it was for PROMO2=1.0) . The roll rate time history also shows little larger amplitudes (peak roll rate is 2.14 versus 2.10) .

3. Thrust is mapped with deadrise force contribution from the outward sidewall only and lateral added mass coefficient C_h=0.8

Comparing these plots (67-68) for PROMO2=16.0 with plots 43-44 where PROMO2=1.0 again only a slight damping effect in roll angle response can be noticed with the number of

transient oscillations being uneffected. Using the P*ABS(P) term the slight damping effect shown in plot 67 is cancelled as shown in plot 69.

The above observations show that the experimentally determined roll damping factor PROMO2=16.0 has only a negligible damping effect. Considering the roll damping term again as it was added to the present XR-3 Loads and Motions Program in 1974, there was a 1/PI - factor which actually cancelled the PI - factor contained in the former expression for the vertical added mass A33S (Section III.A). Since the PI - factor already has been eliminated by correcting the A33S - expression, there is no further need to cancel it in the damping term by the 1/PI - term which therefore also could be eliminated. This change is expected to cause an increase in sidewall roll damping by a factor of PI and has been investigated by an additional run.

4. Thrust is mapped with deadrise force contribution from the outward sidewall only, roll damping term being

   16.0*YSW*YSW*BC2*P

   and lateral added mass coefficient C_h=0.8

From plots 71-72 again only a slight damping effect versus plots 67-68 can be noticed.

The investigation described in this section shows that the roll damping due to vertical wave generation as included in subroutine SIDEWALL is not very effective even if the factor PROMO2 in the damping term is increased from 16.0 to 50.0 . There also is a lack in matching dimensions (statement SDWL2200).

IV. PROPULSION AND RUDDER SUBROUTINES

In all simulation runs executed during this study the XR-3 Loads and Motions Program as given in Ref. 2 has been used except for the modifications mentioned in this work. This simulation program contains Forbes' version [Ref. 9] of 'SUBROUTINE PROP' which included some revisions of the original version given by Leo and Boncal [Ref. 8]. Since in TABLE VII (Section III.B.4) the roll moment contributed by the propulsion system (FKP) is rather small (0.1 to 0.2) an additional run using Leo and Boncal's version has been executed under the conditions as stated for TABLE VII (center of gravity deadrise angle). The steady state values are shown below (in parantheses are the values obtained using Forbes' version) :

pitch angle	0.44(0.45)	draft	5.73(5.81)
roll angle	1.67(1.53)	speed	19.39(19.37)
FYSW	-909.4(-821.9)	FYRUD	- 54.7(32.7)
FYAED	- 21.3(- 20.0)	R*V*AM	888.4(809.2)
FYP	97.0(0.0)		
FKBS	-348.0(-336.4)	FKSS	- 3.0(- 2.7)
FKSW	269.9(212.1)	FKRUD	150.3(- 89.9)
FKAED	- 63.5(- 56.0)	FKP	-305.2(0.14)
ABPB*PHI*Z	299.5(273.5)		
FYD	-729.2(-651.4)	FYH (P/S)	-43/-137(-45/-126)

Regarding these values drastic differences are found for FYP and FYRUD as well as for FKP and FKRUD, though the steady state values for pitch and roll angle, draft and speed are close to those obtained using Forbes' version. The pitch and roll angle responses are given in plots 25-28. Comparing these with the corresponding ones using Forbes' version (plots 13-16) it is seen that Leo and Boncal's version generates more oscillatory roll and pitch angle responses. Therefore a review of subroutine PROP especially the computation of the respective forces and moments has been carried out and are discussed below.

The review resulted in force and moment equations which are identical to those given by Leo and Boncal [Ref. 8]. Another point that supports the supposition to use this version of subroutine PROP is the fact that it provides a reasonable roll moment due to the propulsion system (Forbes' version provides almost zero roll moment). In order to test the effect of changing subroutine PROP to its original form, simulation runs 1. and 2. from the preceding section have been repeated and their time histories for the roll behavior are shown in plots 73-74 and 75-76, respectively. Comparing these with the corresponding ones using Forbes' version of subroutine PROP, plots 61-62 and 63-64, it is observed that the steady state and peak roll angles are larger by about 7 % and the number of transient oscillations is uneffected by this change.

Next a review of subroutine RUDDER has been carried out in order to investigate the cause of the change in sign for FYRUD and FKRUD depending on the propulsion subroutine used (Forbes' or Leo and Boncal's version) although identical RUDDER-subroutines have been used in both cases. The important equations to be considered are :

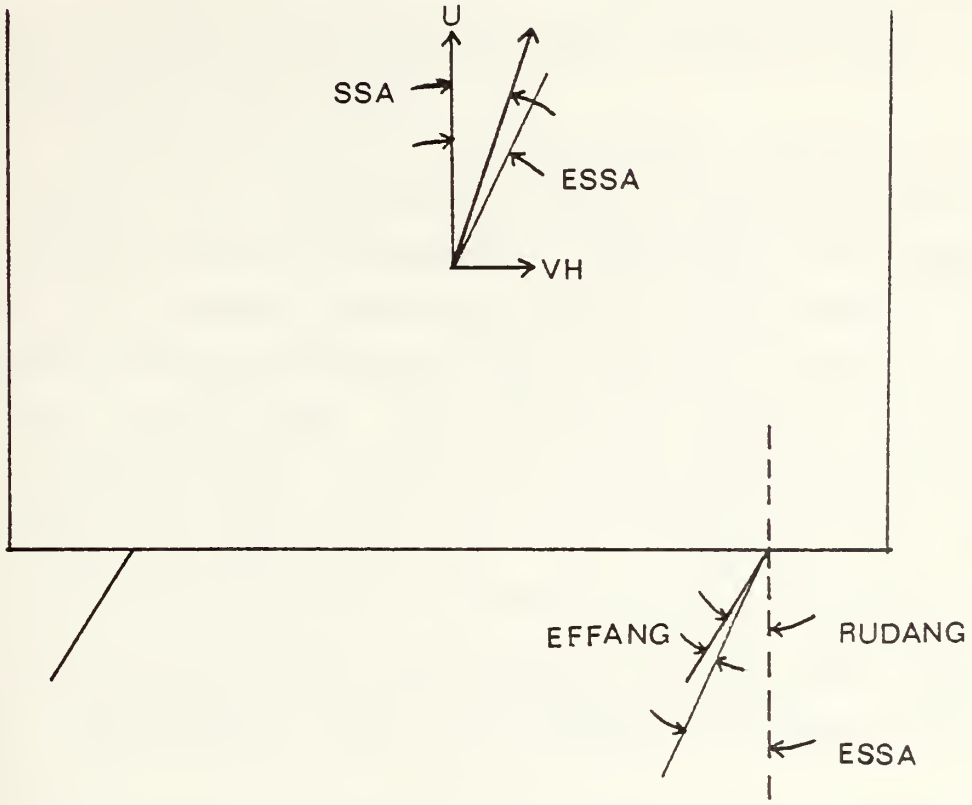
```
DSR=Z+ZS-XR*THETA
ENDFAC=1. + DSR/(DSR+RSPAN)
VH=V + XR*R - ZR*P
EFFANG=RUDANG - ENDFAC*VH/U
FY=RHO*U*U*RAREA*ENDFAC*RCLB*EFFANG
•
FK= -ZR*FY
```

The above equations compute

- draft at the rudder location
- endfactor depending on the rudder length below the craft's keel
- sideslip velocity
- effective rudder angle depending on the craft's forward and sideslip velocities
- lateral force depending on rudder area and effective rudder angle
- roll moment due to rudder .

The sign of the roll moment FK is dependent on the sign of the lateral force FY which depends on the sign of the effective rudder angle EFFANG. This in turn depends of course on the introduced rudder angle, but the magnitude of the second term of this equation (sideslip angle) is responsible for the actual sign of EFFANG. VH/U represents the tangent of the sideslip angle which - applying small angle approximation - is subtracted from the introduced rudder angle (see Figure 9). Since ENDFAC=1.73 and U was the same for both runs, a difference in VH which was larger in Leo and Boncal's version by about 50 % caused the negative sign (versus a positive sign using Forbes' version) for the effective rudder angle EFFANG and thereby FY. So the only way to introduce a change toward an inward roll behavior here (FKRUD was positive) is to first check the input value for RSPAN and second to eventually modify the craft's engines to have larger immersion into the water.

With regard to the first item, if RSPAN would increase, ENDFAC would decrease as would the magnitudes of EFFANG (negative), FY (negative) and FK (positive).



SSA = VH/U	sideslip angle
ESSA=ENDFAC*VH/U	effective sideslip angle
RUDANG	rudder angle
EFFANG	effective rudder angle

Figure 9 - EFFECTIVE RUDDER ANGLE IN A TURN MANEUVER

Considering next the fact that the engines of the XR-3 had been replaced in 1976 a recent measurement of the rudder and propeller location yielded the following data (original input values shown in parantheses) :

XPO = -1.50 (-1.275)
ZPO = -1.333 (-0.604)
XRO = -1.083 (-1.125)
RSPAN= 1.333 (1.21)
RAREA= 1.42 (0.68)

Two of the runs discussed in the preceding section have been repeated using the original roll damping term and the new propulsion and rudder input parameters.

1. Thrust is mapped with deadrise force contributions from both sidewalls with $C_h = 0.4$.

Comparing plots 77-78 with the corresponding ones for the former rudder and propulsion parameters (plots 63-64) the expected effect due to a decrease in FKRUD can be observed resulting in smaller peak roll angle (1.34° versus 1.45°) and a significantly decreased steady state roll angle (0.65° versus 0.99° at t=50 sec). The transient period of the roll angle response in plot 77 shows the same number of transient oscillations as plot 63 but the response did not reach steady state even after 45 sec . The steady state roll angle could be estimated to be about 0.3 to 0.4 degrees.

2. Same conditions as in the previous run but with deadrise force contribution from the outward sidewall only and $C_h = 0.8$.

Regarding plots 79-80 versus plots 71-72 a similar effect as mentioned before is observed. Now the roll angle response shows a more oscillatory transient period. The peak roll angle reduced from 1.46 to 1.36 degrees while the roll angle at t=50 sec changed from 1.34 to 0.97 degrees. For this run the steady state roll angle could be estimated to be about 0.8 degrees since the roll angle response again did not reach steady state for the run using the recently determined rudder and propulsion parameters. The initial small negative roll angle which appeared in the previous run (plot 77) at the moment when the rudder motion is introduced, does not show up any more. The overall roll response shown in plot 79 does not fall off as steeply (compared to plot 77) if, in a turn maneuver, deadrise force contribution from the outward sidewall only is considered.

From these runs it is obvious that the rudder and propulsion parameters of the new engines result in a more favorable XR-3 roll behavior with a significantly less steady state outward roll angle. At the time of this sensitivity study Reference 7 pointed out that there actually is no roll angle indicated by the measuring devices in a port turn at 20 knots and 12 or 15 degrees rudder angle. Keeping the device sensitivity of ±0.5 degrees in mind, it can be concluded that the steady state roll angle provided by the present XR-3 Loads and Motions Program including the before mentioned program modifications by the author, is quite well in agreement with the actual craft data. Further efforts should be undertaken to obtain a better damping effect during the transient period.

Remark :
Although the new engines extend about 0.5 ft deeper into the water than the old engines, the new input value for RSPAN is close to the former value. In Reference 1 the denominator of the second term in the equation for ENDFAC is defined to be the distance from the water surface to the bottom tip of the rudder. The equation for ENDFAC used in the present program accounts for changes in draft DSR in both the numerator and the denominator. The RSPAN-term should then be defined to be the distance from the craft's keel to the bottom tip of the rudder. The author suspects that formerly there has been chosen too large a value for RSPAN in the case of the old engines (RSPAN=1.21 ft, probably from water surface to bottom tip of the rudder). Since the bottom tip of the rudder and the center of the propeller were located at almost the same distance from the craft's keel the magnitudes of ZPO and RSPAN should be about the same which is not true for the former chosen values. From these observations the author concludes that until now a too optimistic roll behavior resulted due to a too large value for RSPAN.

V. CONCLUSIONS AND RECOMMENDATIONS

The preceding sections of this chapter reflect the results of an investigation on how the XR-3 roll behavior in turn maneuvers at 20 kn simulated with the Loads and Motions Program is affected by certain changes in parameters and forces. The results of this sensitivity study are summarized as follows :

* Added mass effect

A reformulation of the vertical added mass computation which reduced the A33s-value by a factor of 1/PI had only a little effect in changing steady state draft, pitch angle and required thrust for constant speed in straight runs. In turn maneuvers this change resulted in less damped responses for pitch and roll angle and affected the steady state values for pitch angle by +8.3 % , roll angle by -1.0 % and draft by +1.4 % . Considering the roll behavior, the effect of reducing the A33s-value by a factor of 1/PI in the vertical added mass computation was negligible.

A change in the lateral added mass coefficient C_h=0.4 to 0.8 had the effect of reducing the amplitudes of the transient oscillations and the steady state roll angle by 0.1 degree toward the experimentally measured value. Since in a turn maneuver with 15 degrees rudder angle an unstable craft behavior showed up which had not been experienced in practice, the value of C_h=0.8 is not realistic if deadrise force contributions from both sidewalls are considered. If deadrise force contribution from the outward sidewall only

is used in the simulation program the increase in lateral added mass coefficient causes an increase in the steady state roll angle by about 0.1 degree. But since now the roll angle response is quite significantly damped and resembles a step as it does in practice, the choice of the larger coefficient (0.8) seems to be appropriate for the case of the deadrise force contributed from the outward sidewall only.

* Deadrise angle effect

The deadrise angles over the length of the curved XR-3 sidewalls are not uniform. Changing the deadrise angle which is used in the deadrise force computation from the transom (78.8°) to the center of gravity (58.5°) resulted in more damped responses for pitch and roll motion in turn maneuvers. For all chosen rudder angles generating port turns at 20 kn the steady state roll angle changed favorably by 23 to 38 % toward the corresponding roll angle measured experimentally and documented in Ref. 6.

* Cross-flow drag coefficient

Changing the cross-flow drag coefficient (CDSW=1.28 for a long flat plate) to lower values, e.g. CDSW=1.00 , the testcraft's simulated roll behavior could be forced to match the measured steady state values. But since this coefficient has been chosen arbitrarily and cannot be declared to be appropriate for the actual XR-3 sidewalls (CDSW=1.0 means that there is no effective drag coefficient) this CDSW-value has not been considered any longer. Another suggested cross-flow drag coefficient CDSW=1.16 [Ref. 3] resulted in about 5 % reduction in steady state roll angle and a shorter transient period (about 20 %) with smaller amplitudes of oscillation than did the runs using CDSW=1.28.

* Thrust mapping

Performing thrust mapping in the simulation runs using the data provided in Ref. 6 and assuming that both engines lose equal amounts of thrust in turn maneuvers, the simulated steady state roll angles could be shown to agree better with the measured angles by about another 10 % but the roll angle response did not quite reach steady state even after 45 seconds.

* Deadrise force from outward sidewall only

The simulation runs executed with the deadrise force computed for the outward sidewall only and thrust mapping as done before, showed less agreement for both C_h=0.4 (0.8) with the corresponding measured steady state roll angles than did the runs considering deadrise forces from both sidewalls. But for C_h=0.8 the roll angle response was significantly damped and looked more like a step, as was experienced in practice.

* Vertical location of the center of gravity

The given value for the vertical location of the center of gravity (2.54 ft above the keel) might not be quite correct due to the difficulties in experimentally determining it. The significant effect of the vertical center of gravity location on the XR-3 roll behavior is obvious from Figures 1 and 8 and the discussion in Section III.F. Since it controls exceedingly the XR-3 roll behavior it is important that future investigators obtain an accurate measurement of the C.G. location before taking testcraft data.

* Subroutine PROP

A review of the propulsion subroutine revealed that the force and moment calculations as given by Leo and Boncal (Ref. 8) should be used instead of the version stated by Forbes (Ref. 9). This change results in a 7 % larger outward steady state roll angle but it provides a reasonable roll moment due to the propulsion system.

* Roll damping due to vertical wave generation

The roll damping calculation included in subroutine SIDEWALL has only a negligible effect on the craft's net roll behavior over the range of the damping factor 1.0<PROM02<50.0 . Since there also is a discrepancy in the dimension of the roll damping term the source of this part of the program should be investigated.

* Suggested areas for further investigation

During the studies undertaken with the XR-3 Loads and Motion Program the author found the following points either in the input data from the testcraft or in the program that require further investigation :

- Rudder/thrust angle

As learned from Ref. 7 the rudder/thrust motion is directly introduced to the port engine while the starboard engine follows this via a metal bar connecting both engines. The starboard rudder and thrust vector may be off by 2 or 3 degrees to either side, depending on the direction of the rudder/thrust action. Thereby the roll behavior will certainly be effected. Since rudder/thrust mapping is available in the Loads and Motion Program, it is important that accurate data be collected for each engine during a test run.

- XR-3 weight

During each test run there is a possibility that the weight is not exact since, as learned from Ref. 7, the testcraft takes on water in the seals and thereby its weight increases causing larger draft which also effects the roll behavior. This additional weight can be substantial and attempts should be made to measure or estimate the additional weight to be used in the Loads and Motion Program.

- Cross-flow drag coefficient

Further efforts should be undertaken to establish the proper value of the cross-flow drag coefficient since CDSW=1.28 might not be quite appropriate for the actual shape of the XR-3 sidewalls.

- Sideslip velocity

Those parts of the Loads and Motions Program where terms contributing to the lateral velocity V are computed should be reviewed since a large value of V may result in a change in the effective rudder angle from positive to negative.

In this sensitivity study it has been shown that the most significant effect on the simulated XR-3 roll behavior are contributed by

* deadrise angle

* vertical location of the center of gravity

* rudder and propeller location .

Less significant effects are contributed by

* thrust mapping

* cross-flow drag coefficient .

For further studies concerned with the XR-3 Loads and Motions Program for improved roll behavior representation it is recommended to use

- the reformulated equation for the vertical added mass A33
- deadrise angle at the center of gravity location
- deadrise force contribution from the outward sidewall only
- subroutine PROP as given by Leo and Boncal and in Appendix C of this thesis
- thrust and rudder mapping.

APPENDIX A

PLOTS

In the table given below are listed all plots with the respective parameters used in the corresponding simulation run. The table contains the following abbreviations :

COEF	coefficient	CG	center of gravity
CDSW	sidewall drag	C_h	lateral added mass coef.
ch4	chapter IV		
DRANG	deadrise angle	DF16	PROMO2=16.0
PA	pitch angle	PR	pitch rate
RA	roll angle	RR	roll rate
REFTAB	refer to table	RUDANG	rudder angle
TR	Transom		

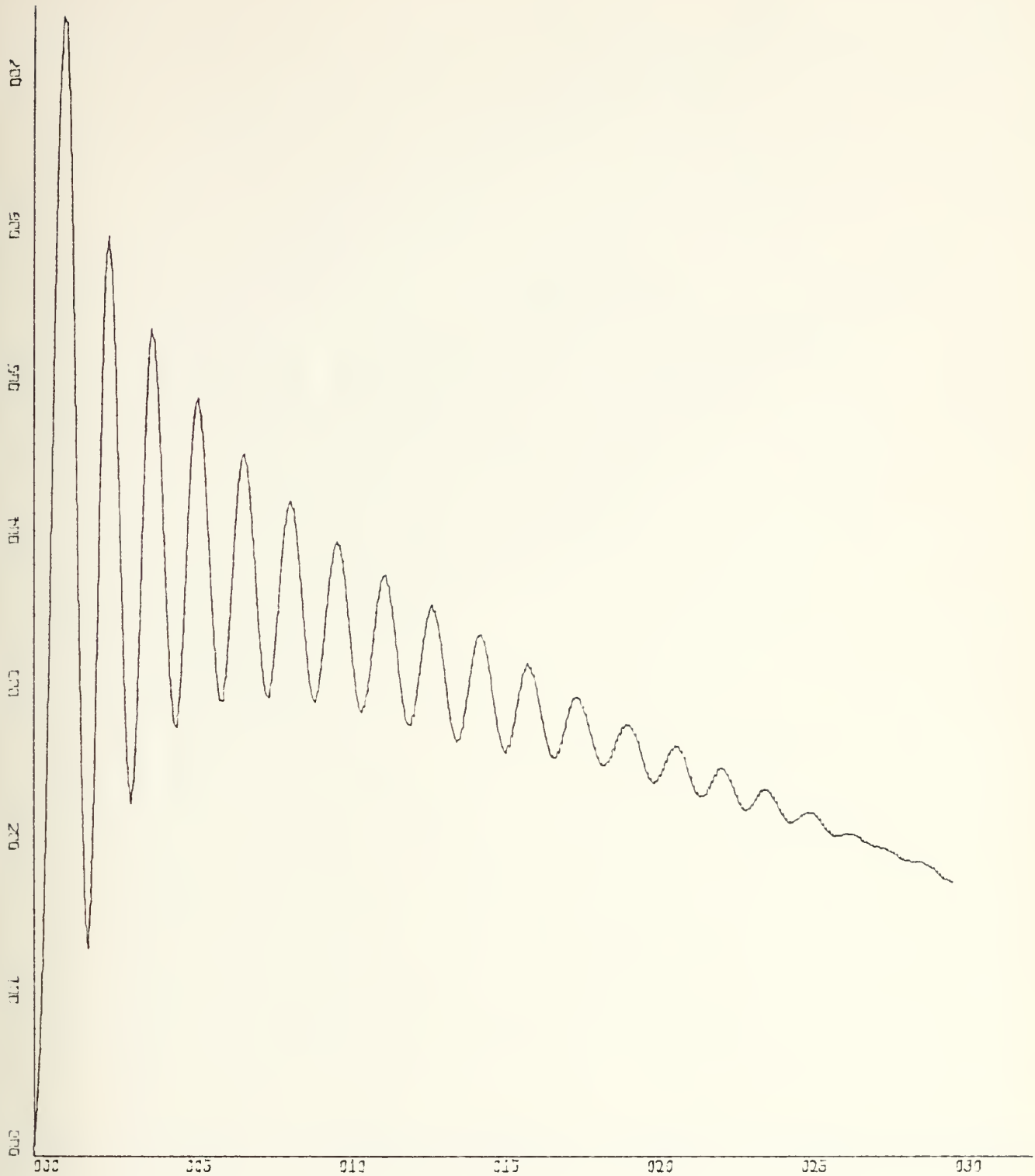
L-B Leo and Boncal's version of subroutine 'PROP' used
P*|P| or P*PI P replaced by ... in SDWL2200 (Section III.G)
ZS-0.1 vertical location of CG is 2.54 - 0.1 (ft)

PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL- FORCES	REMARK
1	1	RA	35	TR	0.4	1.28	no	both	no
2	1	PA	35	TR	0.4	1.28	no	both	PBAR
3	1	RA	35	TR	0.4	1.28	no	both	with
4	1	PA	35	TR	0.4	1.28	no	both	PBAR
5	4	RA	15	TR	0.4	1.28	no	both	
6	4	RR	15	TR	0.4	1.28	no	both	old
7	4	PA	15	TR	0.4	1.28	no	both	A33s
8	4	PR	15	TR	0.4	1.28	no	both	

PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL-FORCES	REMARK
9	4,6	RA	15	TR	0.4	1.28	no	both	
10	4,6	RR	15	TR	0.4	1.28	no	both	
11	4,6	PA	15	TR	0.4	1.28	no	both	
12	4,6	PR	15	TR	0.4	1.28	no	both	
13	6	RA	15	CG	0.4	1.28	no	both	
14	6	RR	15	CG	0.4	1.28	no	both	
15	6	PA	15	CG	0.4	1.28	no	both	
16	6	PR	15	CG	0.4	1.28	no	both	
17	6	RA	15	CG	0.8	1.28	no	both	
18	6	RR	15	CG	0.8	1.28	no	both	
19	6	RA	12	TR	0.4	1.28	no	both	
20	6	RR	12	TR	0.4	1.28	no	both	
21	6	RA	12	CG	0.4	1.28	no	both	
22	6	RR	12	CG	0.4	1.28	no	both	
23	6	RA	12	CG	0.8	1.28	no	both	
24	6	RR	12	CG	0.8	1.28	no	both	
25	ch4	RA	15	CG	0.4	1.28	no	both	L-B
26	ch4	RR	15	CG	0.4	1.28	no	both	L-B
27	ch4	PA	15	CG	0.4	1.28	no	both	L-B
28	ch4	PR	15	CG	0.4	1.28	no	both	L-B
29	8	RA	15	CG	0.4	1.28	no	both	
30	8	RR	15	CG	0.4	1.28	no	both	
31	8	RA	15	CG	0.4	1.16	no	both	
32	8	RR	15	CG	0.4	1.16	no	both	
33	10	RA	12	CG	0.4	1.28	yes	both	
34	10	RR	12	CG	0.4	1.28	yes	both	
35	10	RA	12	CG	0.8	1.28	yes	both	
36	10	RR	12	CG	0.8	1.28	yes	both	
37	10	RA	12	CG	0.4	1.16	yes	both	
38	10	RR	12	CG	0.4	1.16	yes	both	
39	10	RA	12	CG	0.8	1.16	yes	both	
40	10	RR	12	CG	0.8	1.16	yes	both	

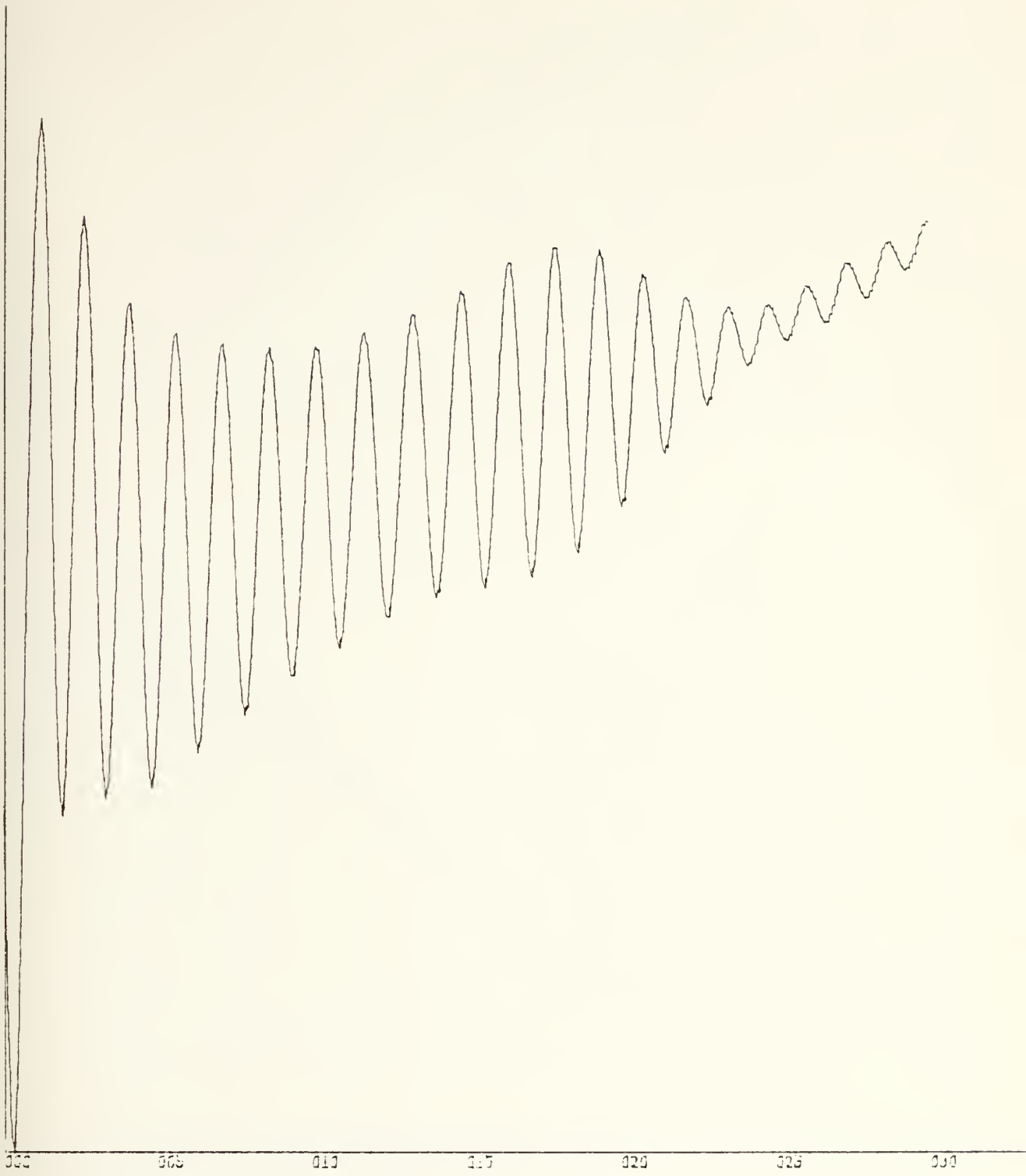
PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL-FORCES	REMARK
41	11	RA	12	CG	0.4	1.28	yes	one	
42	11	RR	12	CG	0.4	1.28	yes	one	
43	11	RA	12	CG	0.8	1.28	yes	one	
44	11	RR	12	CG	0.8	1.28	yes	one	
45	11	RA	12	CG	0.4	1.16	yes	one	
46	11	RR	12	CG	0.4	1.16	yes	one	
47	11	RA	12	CG	0.8	1.16	yes	one	
48	11	RR	12	CG	0.8	1.16	yes	one	
49	12	RA	15	CG	0.4	1.28	no	both	ZS-0.1
50	12	RR	15	CG	0.4	1.28	no	both	ZS-0.1
51	12	RA	15	CG	0.4	1.28	no	both	ZS-0.2
52	12	RR	15	CG	0.4	1.28	no	both	ZS-0.2
53	12	RA	15	CG	0.4	1.28	no	both	ZS-0.3
54	12	RR	15	CG	0.4	1.28	no	both	ZS-0.3
55	13	RA	12	CG	0.4	1.28	yes	both	ZS-0.1
56	13	RR	12	CG	0.4	1.28	yes	both	ZS-0.1
57	13	RA	12	CG	0.4	1.28	yes	both	ZS-0.2
58	13	RR	12	CG	0.4	1.28	yes	both	ZS-0.2
59	13	RA	12	CG	0.4	1.28	yes	both	ZS-0.3
60	13	RR	12	CG	0.4	1.28	yes	both	ZS-0.3
61	ch4	RA	12	CG	0.4	1.28	no	both	DF16
62	ch4	RR	12	CG	0.4	1.28	no	both	DF16
63	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
64	ch4	RR	12	CG	0.4	1.28	yes	both	DF16
65	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
66	ch4	RR	12	CG	0.4	1.28	yes	both	P*|P|
67	ch4	RA	12	CG	0.8	1.28	yes	one	DF16
68	ch4	RR	12	CG	0.8	1.28	yes	one	DF16
69	ch4	RA	12	CG	0.8	1.23	yes	one	DF16
70	ch4	RR	12	CG	0.8	1.28	yes	one	P*|P|
71	ch4	RA	12	CG	0.8	1.28	yes	one	DF16
72	ch4	RR	12	CG	0.8	1.28	yes	one	P*PI

PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL-FORCES	REMARK
73	ch4	RA	12	CG	0.4	1.28	no	both	DF16
74	ch4	RR	12	CG	0.4	1.28	no	both	L-B
75	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
76	ch4	RR	12	CG	0.4	1.28	yes	both	L-B
77	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
78	ch4	RR	12	CG	0.4	1.28	yes	both	P*PI
79	ch4	RA	12	CG	0.8	1.28	yes	one	new
80	ch4	RR	12	CG	0.8	1.28	yes	one	Rud



PLOT 1

for applied parameters see first page of this appendix

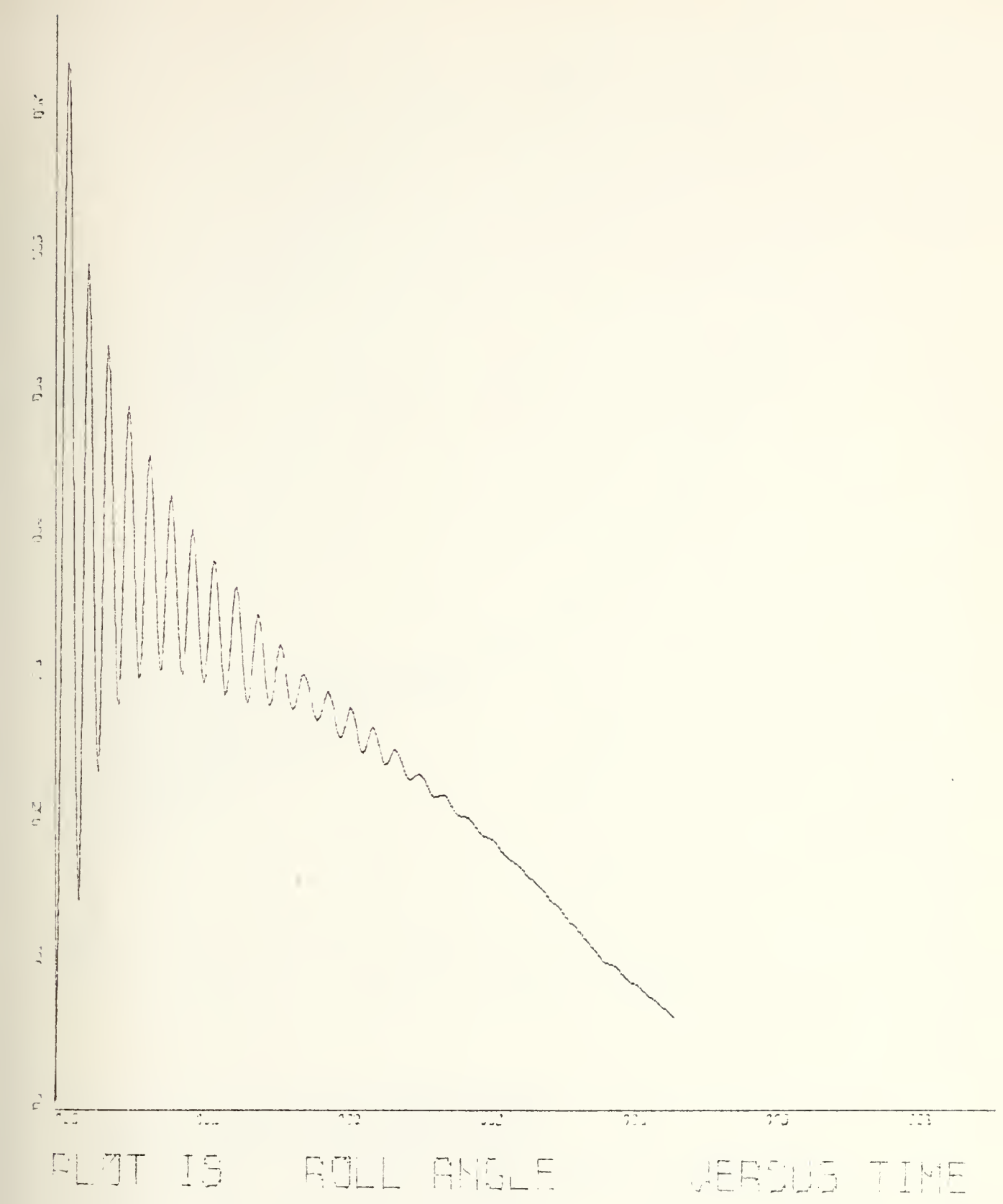


PLOT IS PITCH ANGLE VERSUS TIME

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

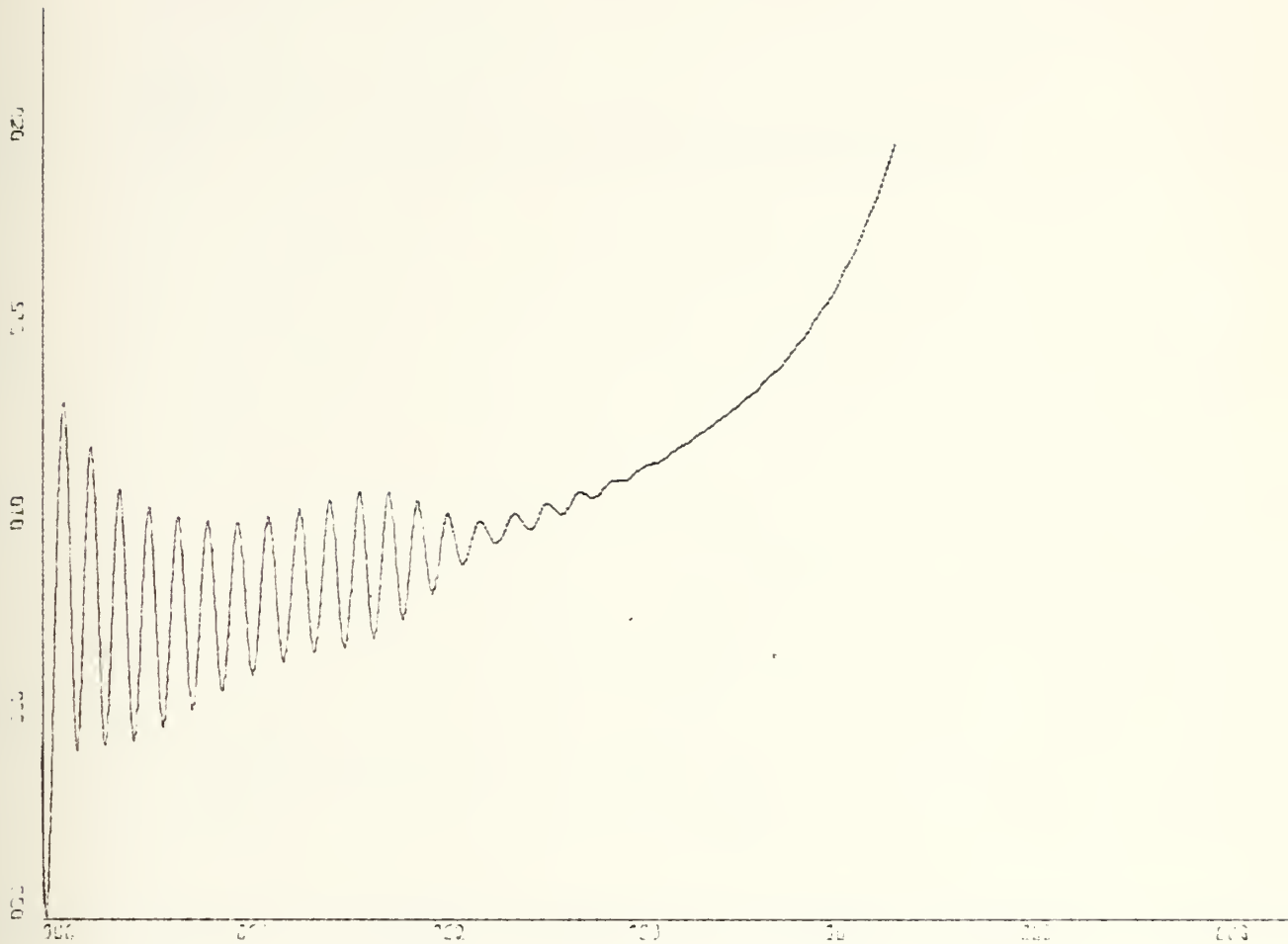
PLOT 2

for applied parameters see first page of this appendix



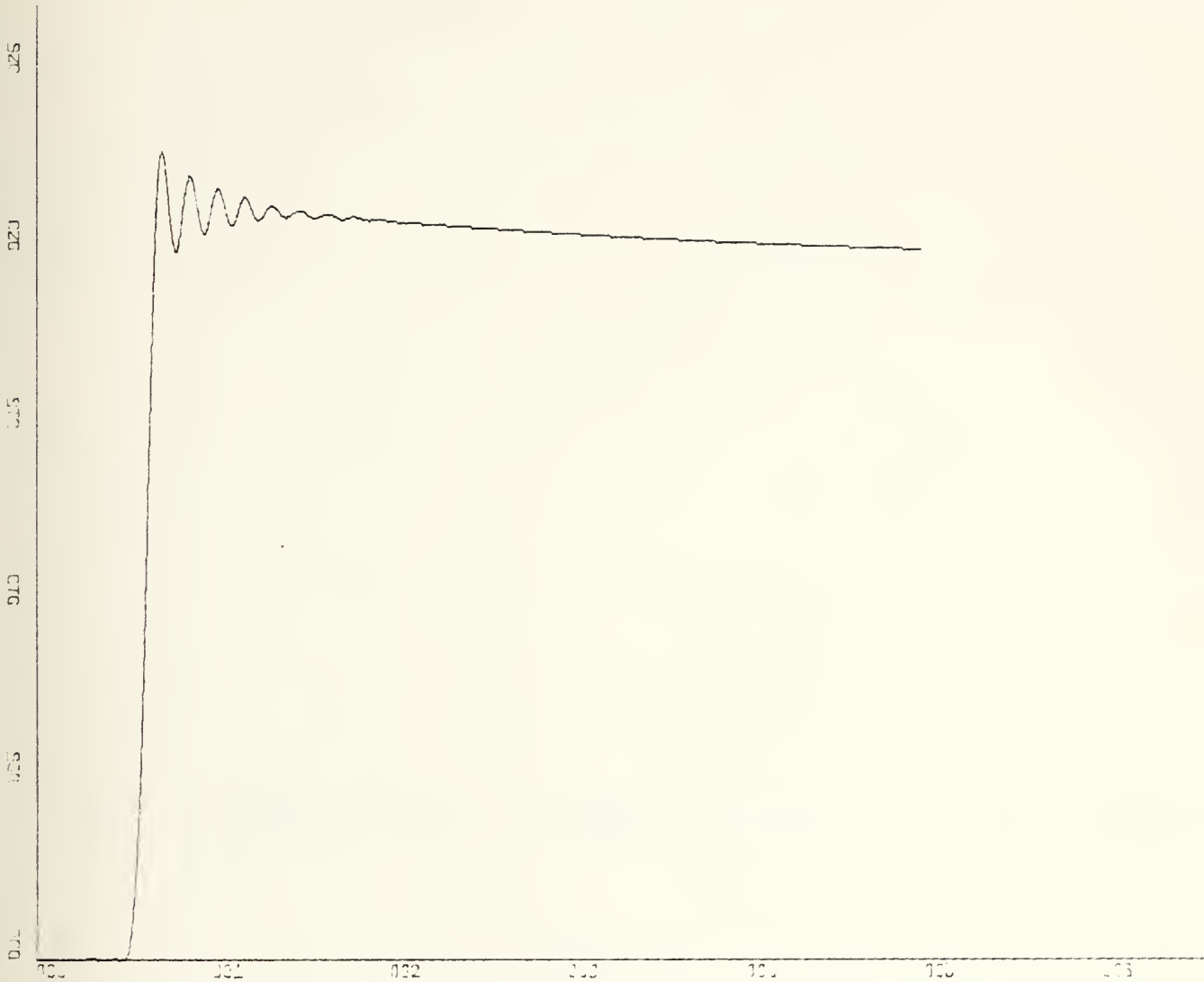
PLOT 3

for applied parameters see first page of this appendix



PLOT 4

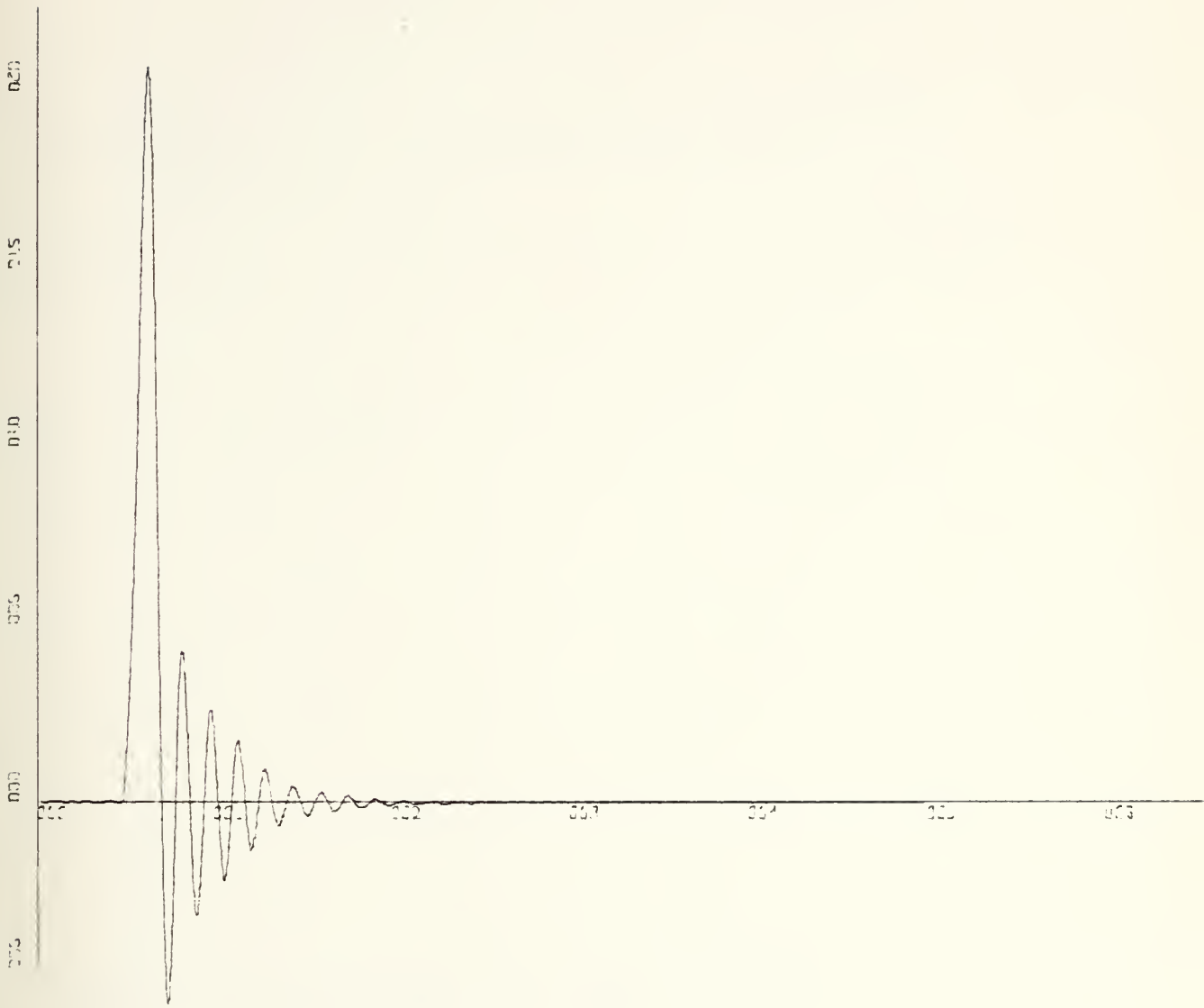
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROD2 , TURN 20 KN , RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

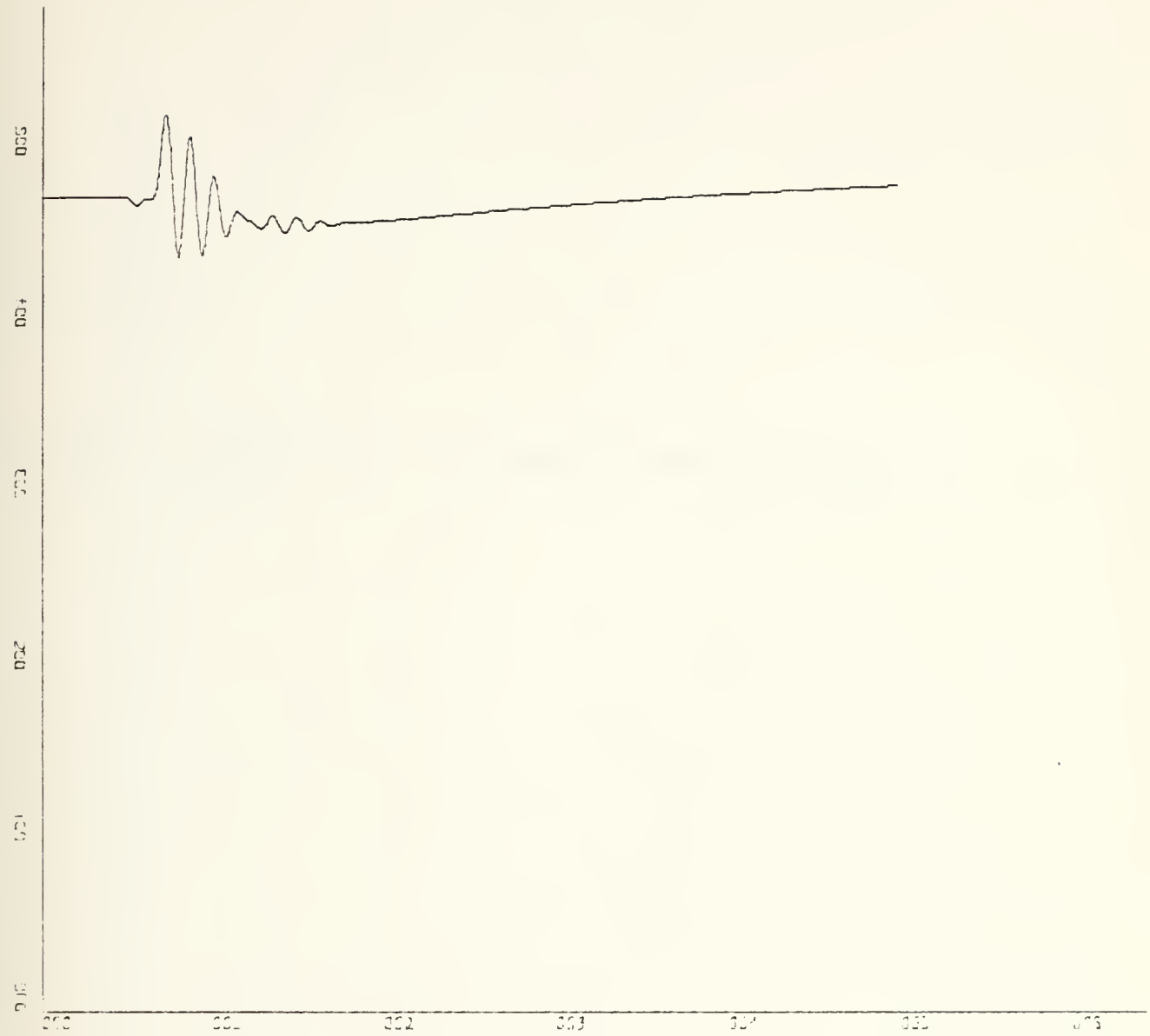
PLOT 5

for applied parameters see first page of this appendix



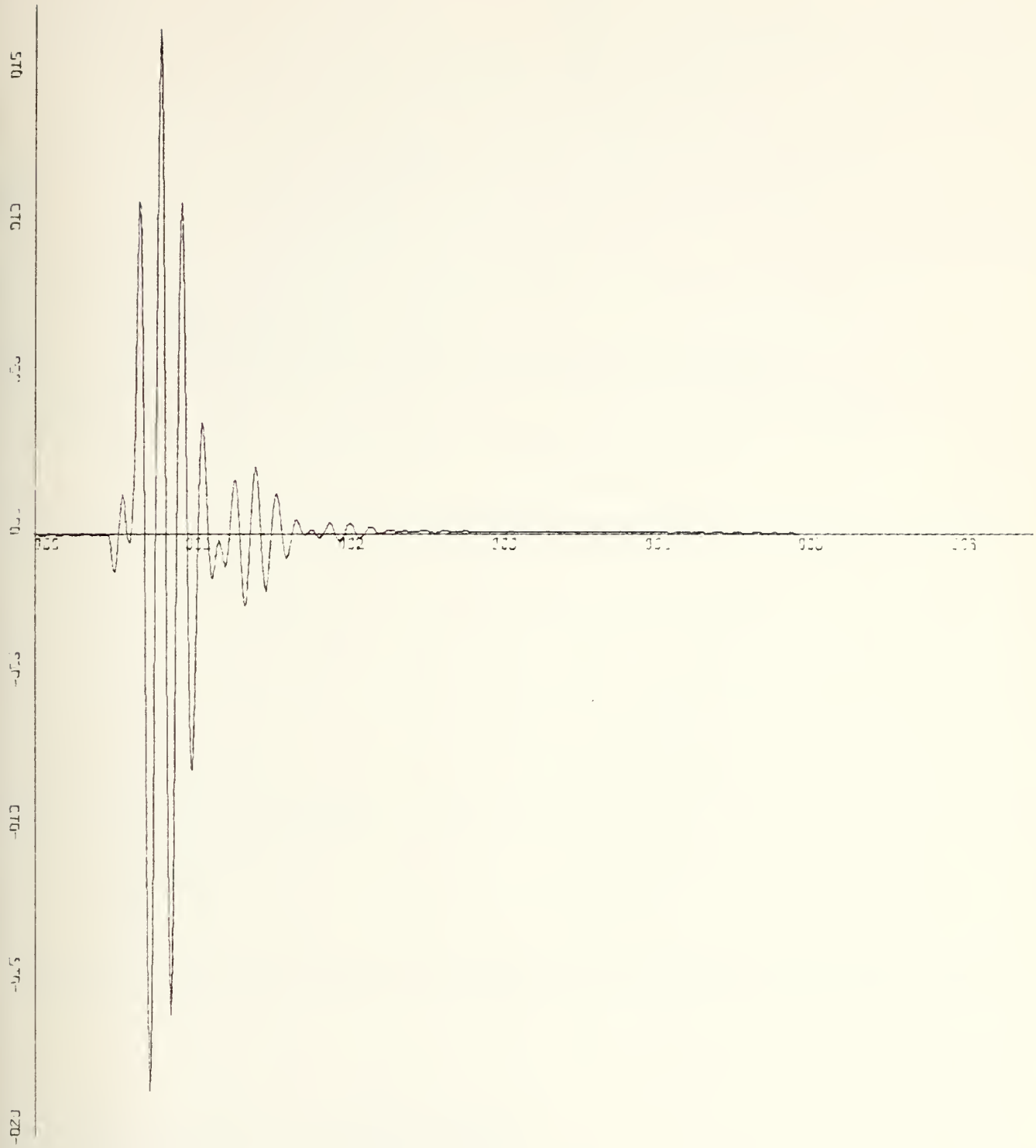
PLOT 6

for applied parameters see first page of this appendix



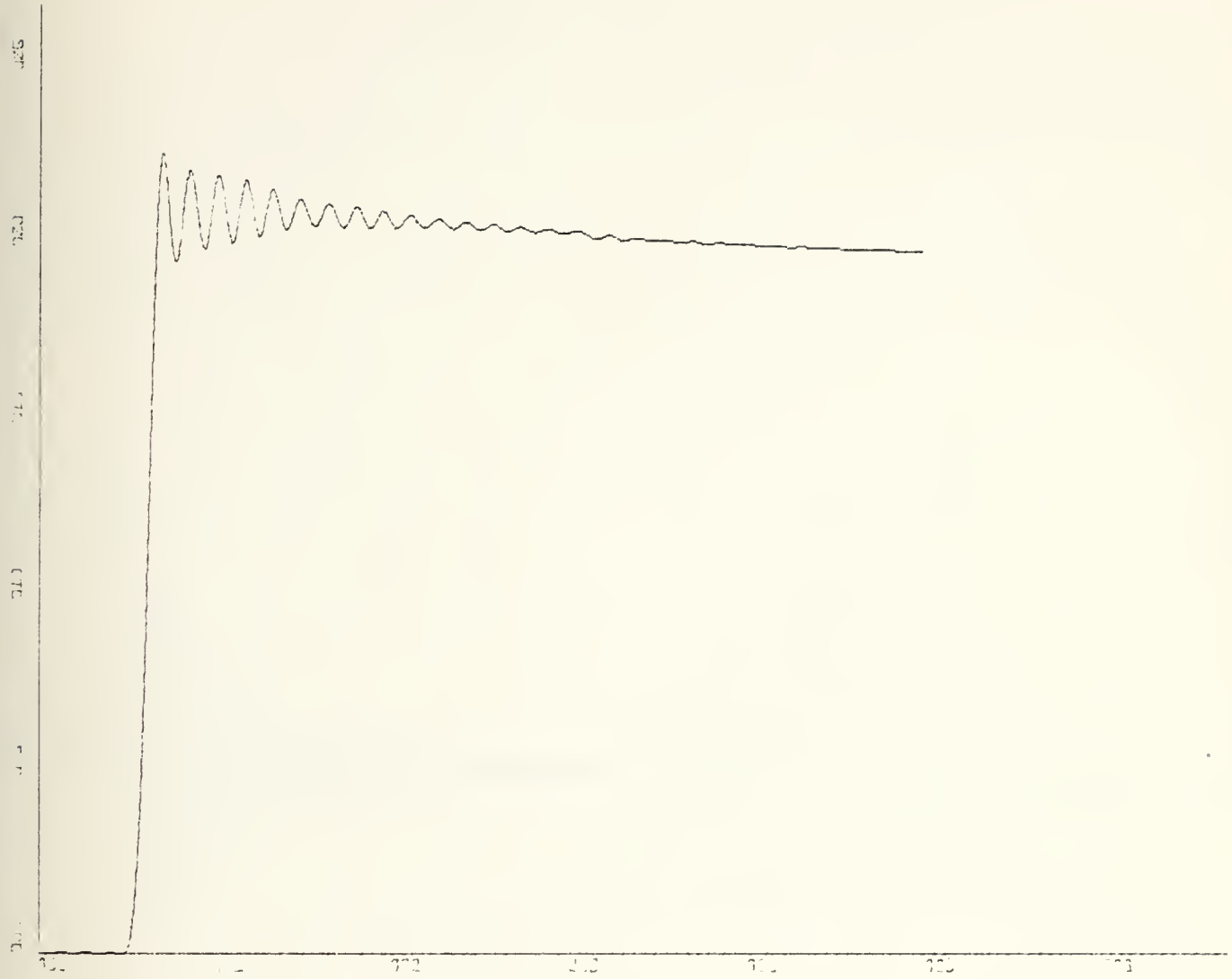
PLOT 7

for applied parameters see first page of this appendix



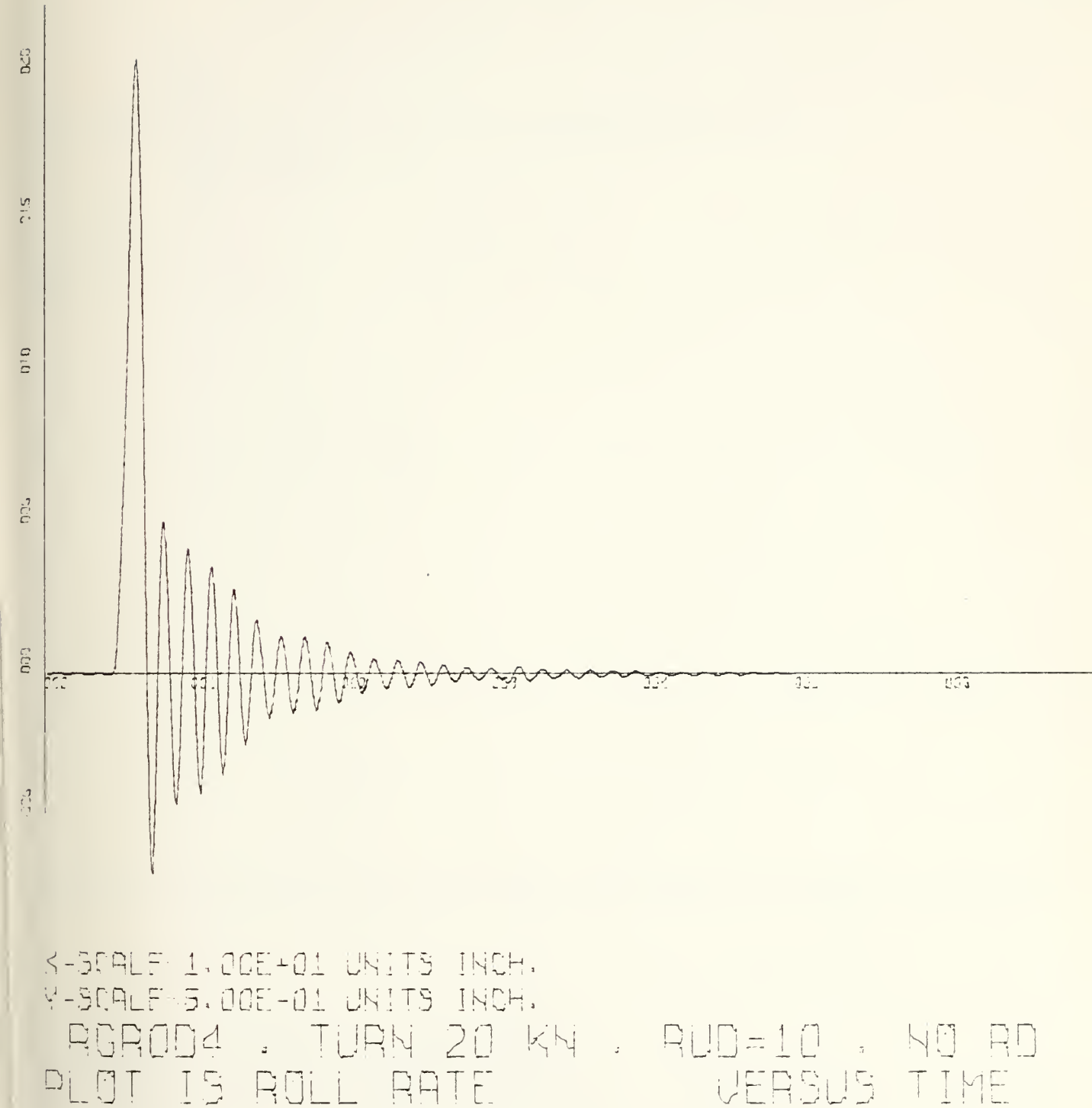
PLOT 8

for applied parameters see first page of this appendix



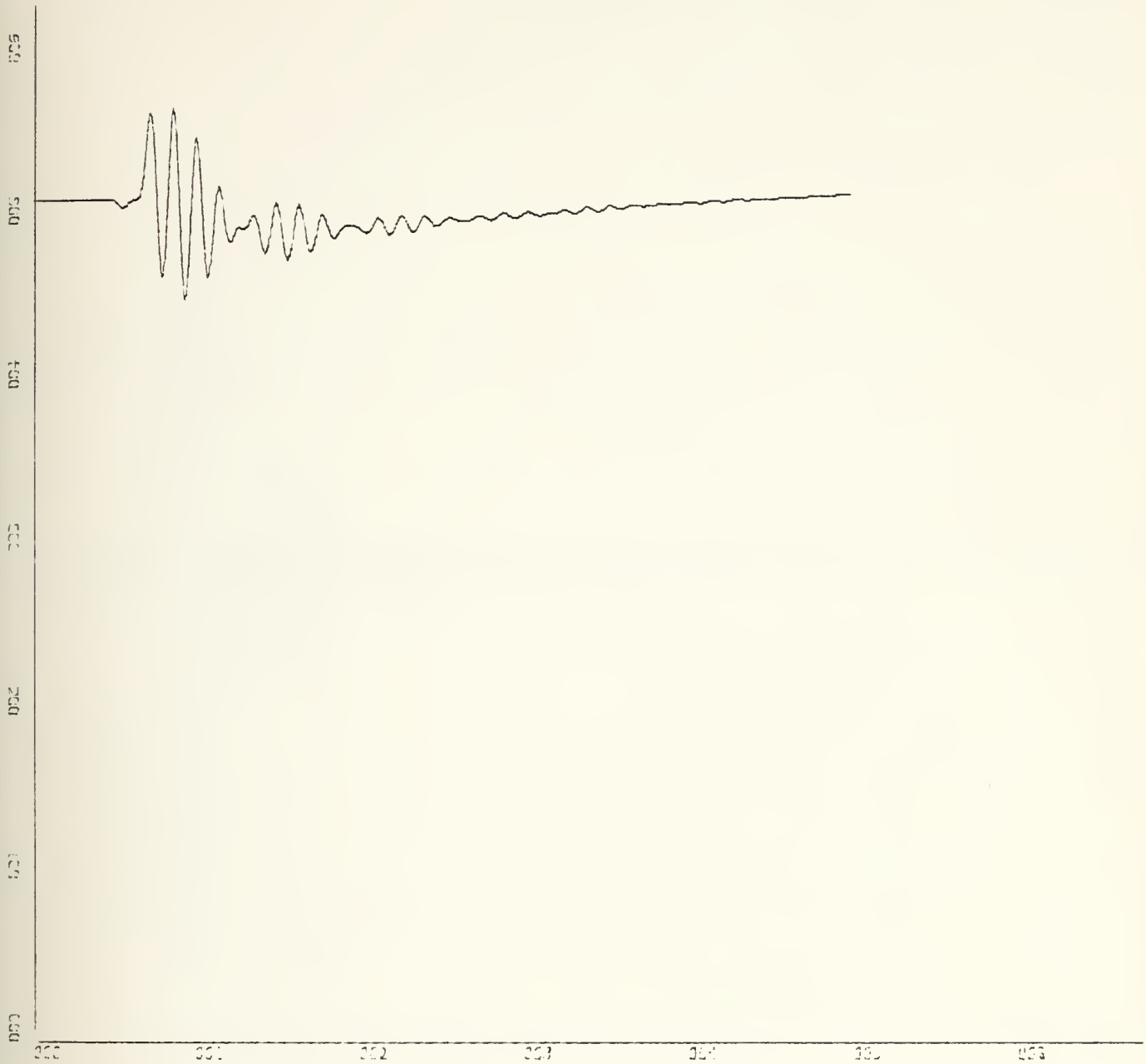
PLOT 9

for applied parameters see first page of this appendix



PLOT 10

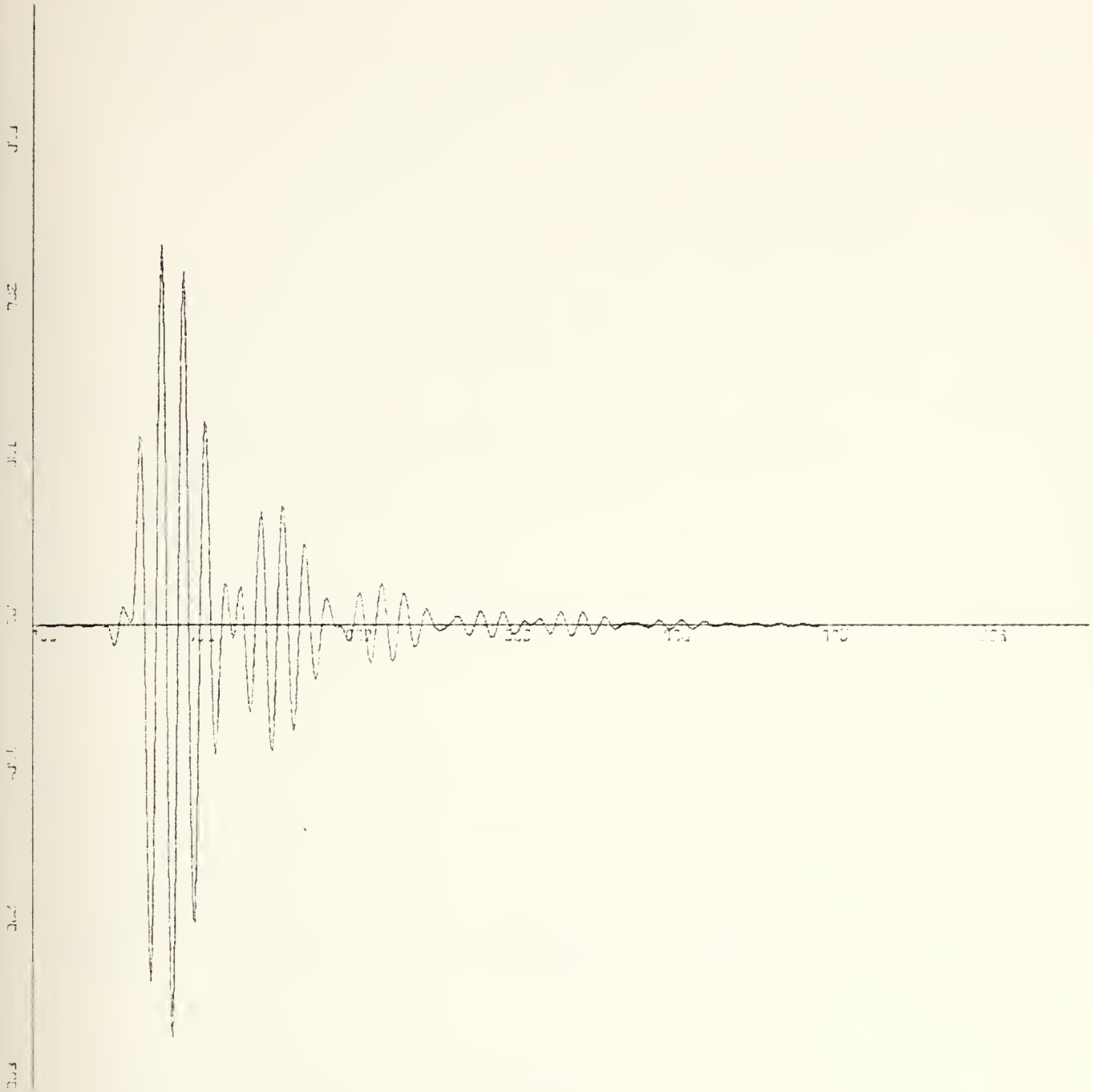
for applied parameters see first page of this appendix



X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 1.00E-01 UNITS INCH.
RCR004 , TURN 20 KN , RUD=10 , NO RD
PLOT IS PITCH ANGLE VERSUS TIME

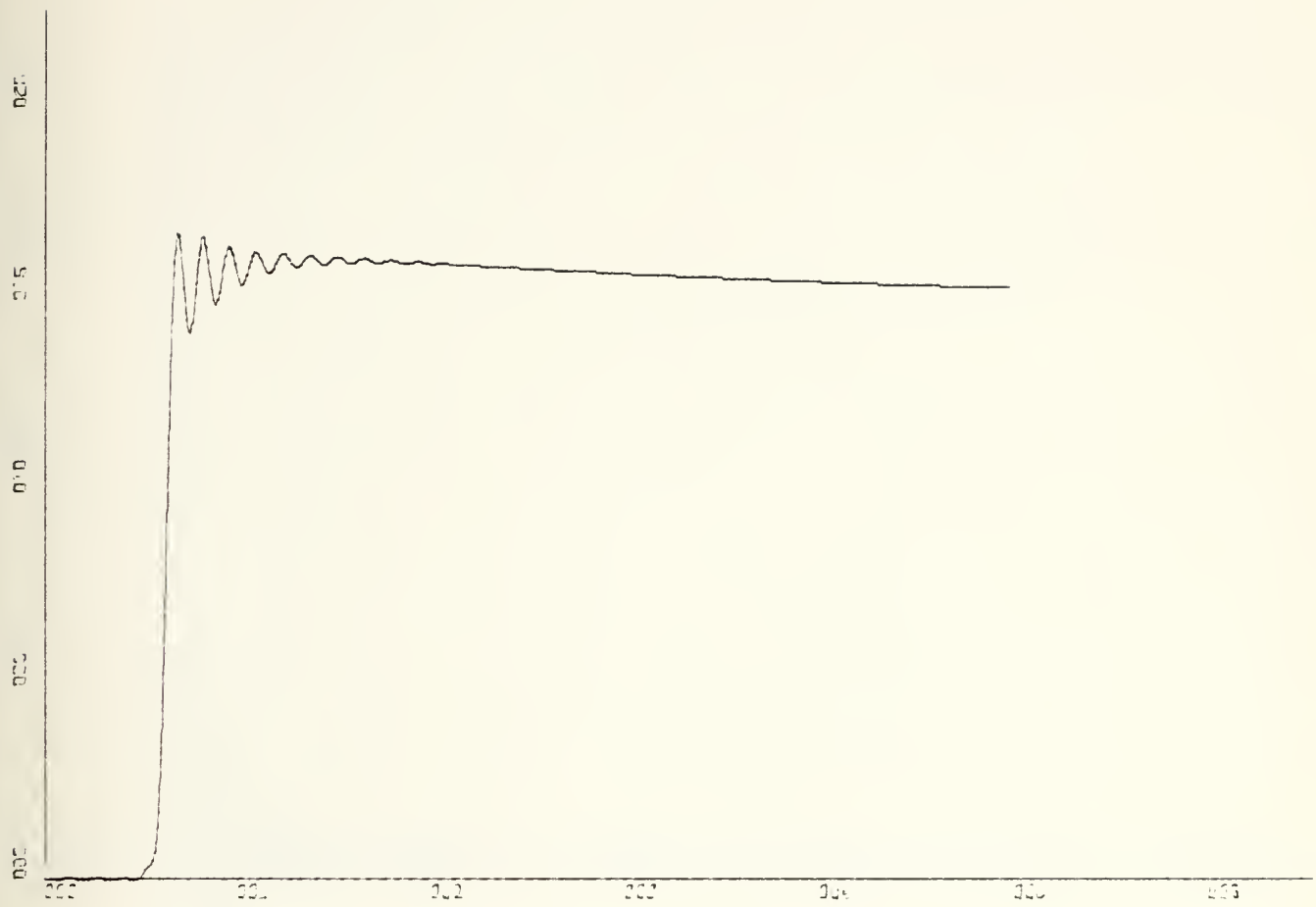
PLOT 11

for applied parameters see first page of this appendix



PLOT 12

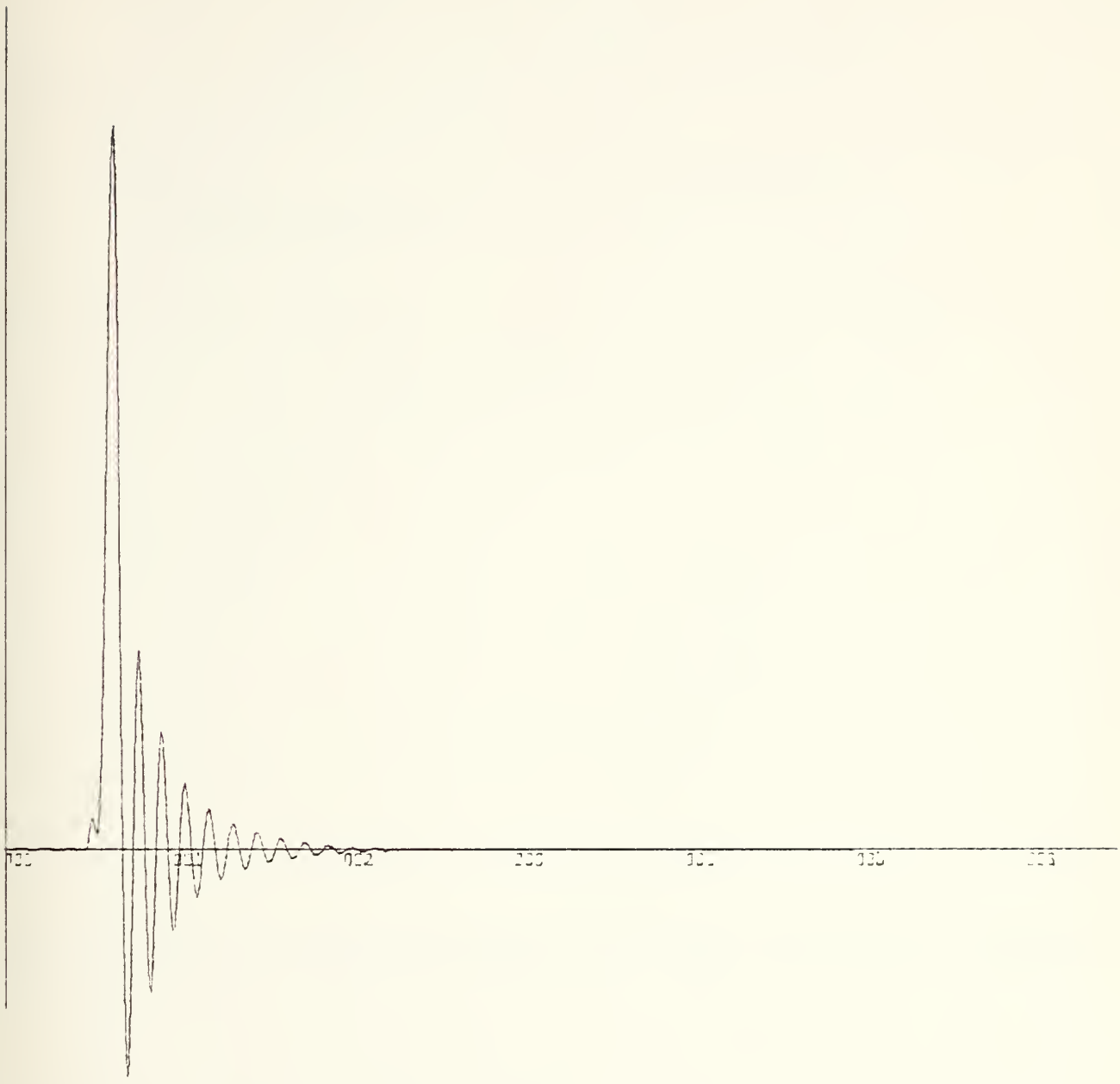
for applied parameters see first page of this appendix



X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 5.00E-01 UNITS INCH.
RGR005 , TURN 20 KN , RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 13

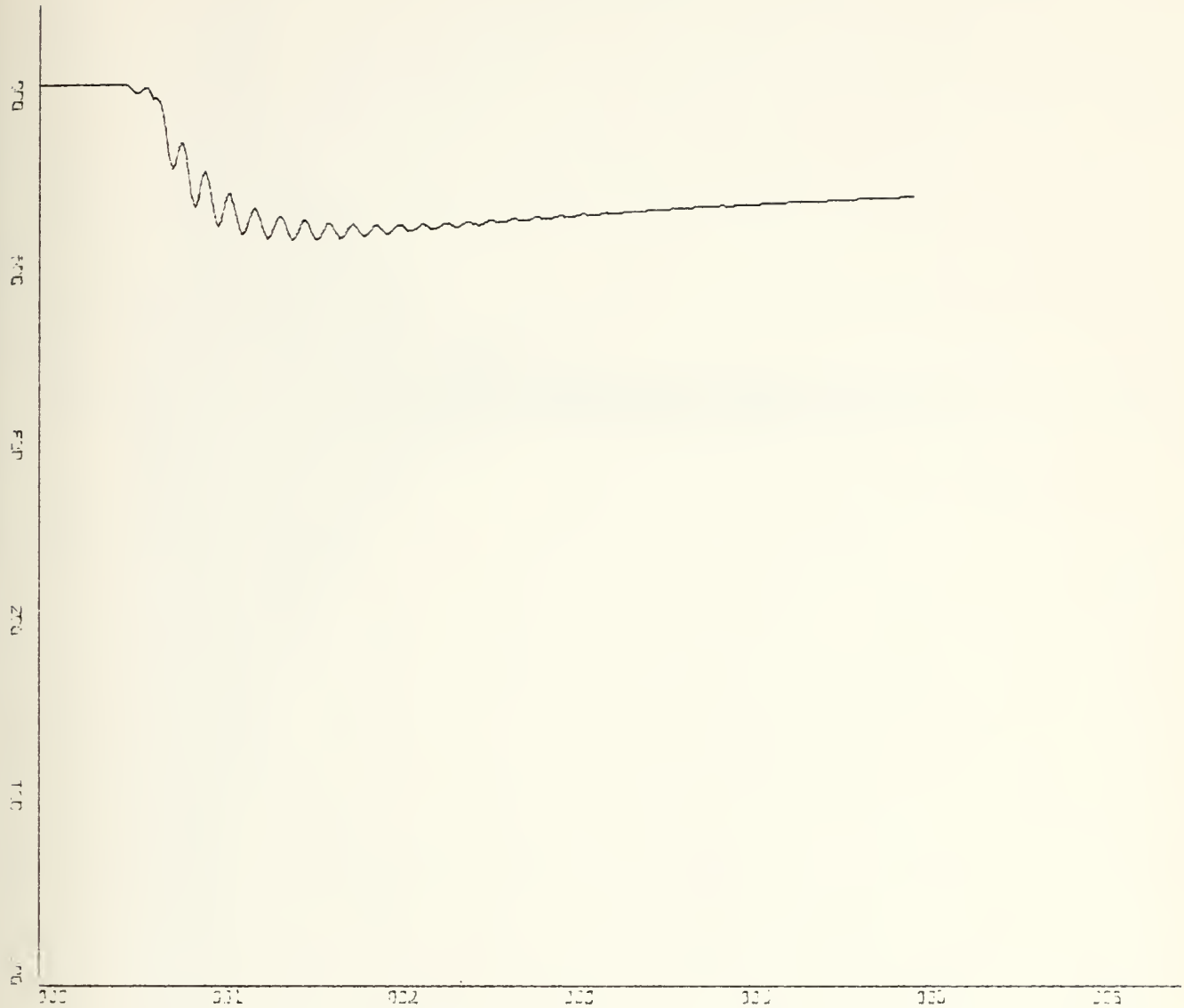
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROD5 , TURN 20 KN , RUDM=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 14

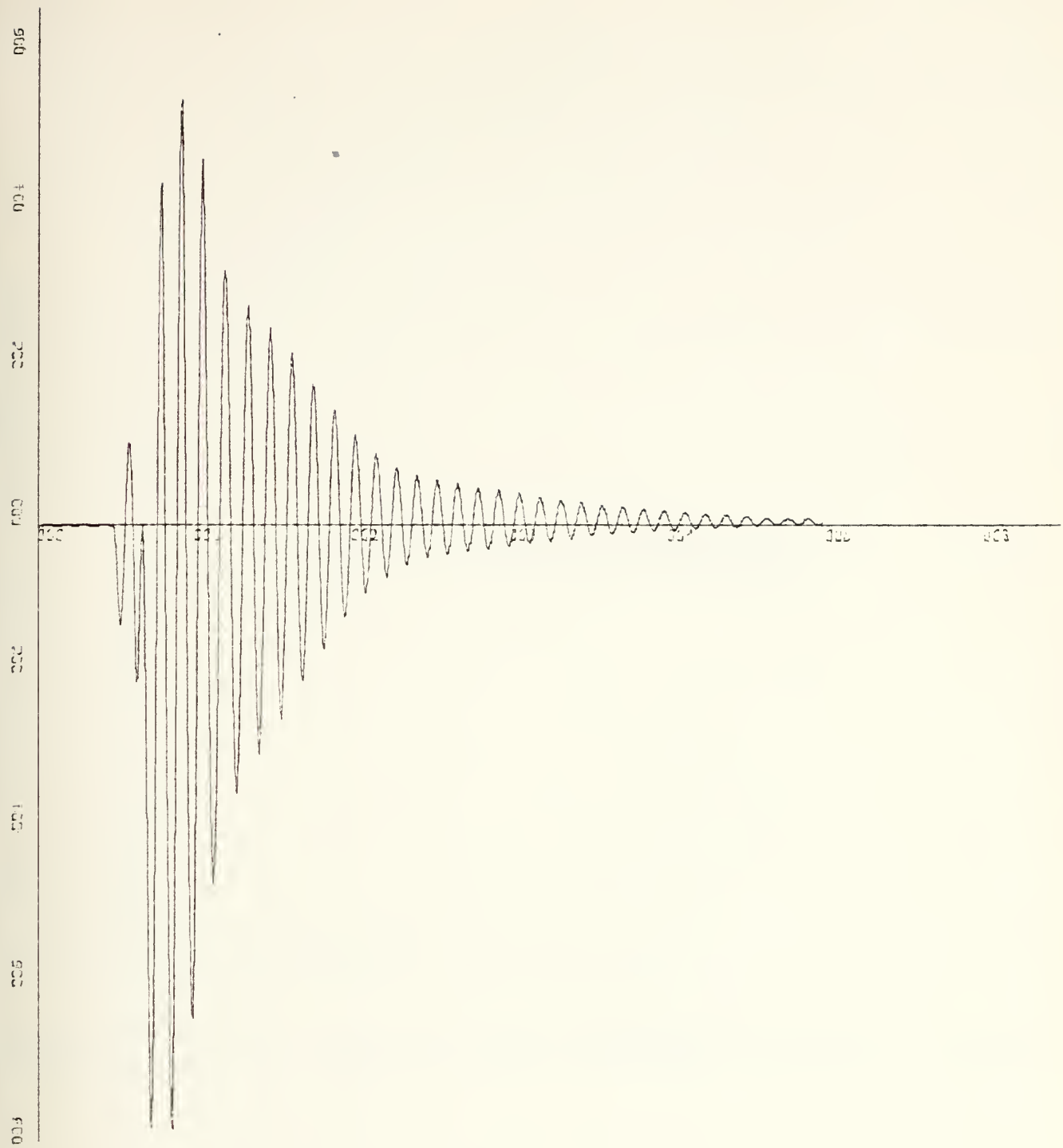
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.
RGROD5 , TURN 20 KN , RUDM=15
PLOT IS PITCH ANGLE VERSUS TIME

PLOT 15

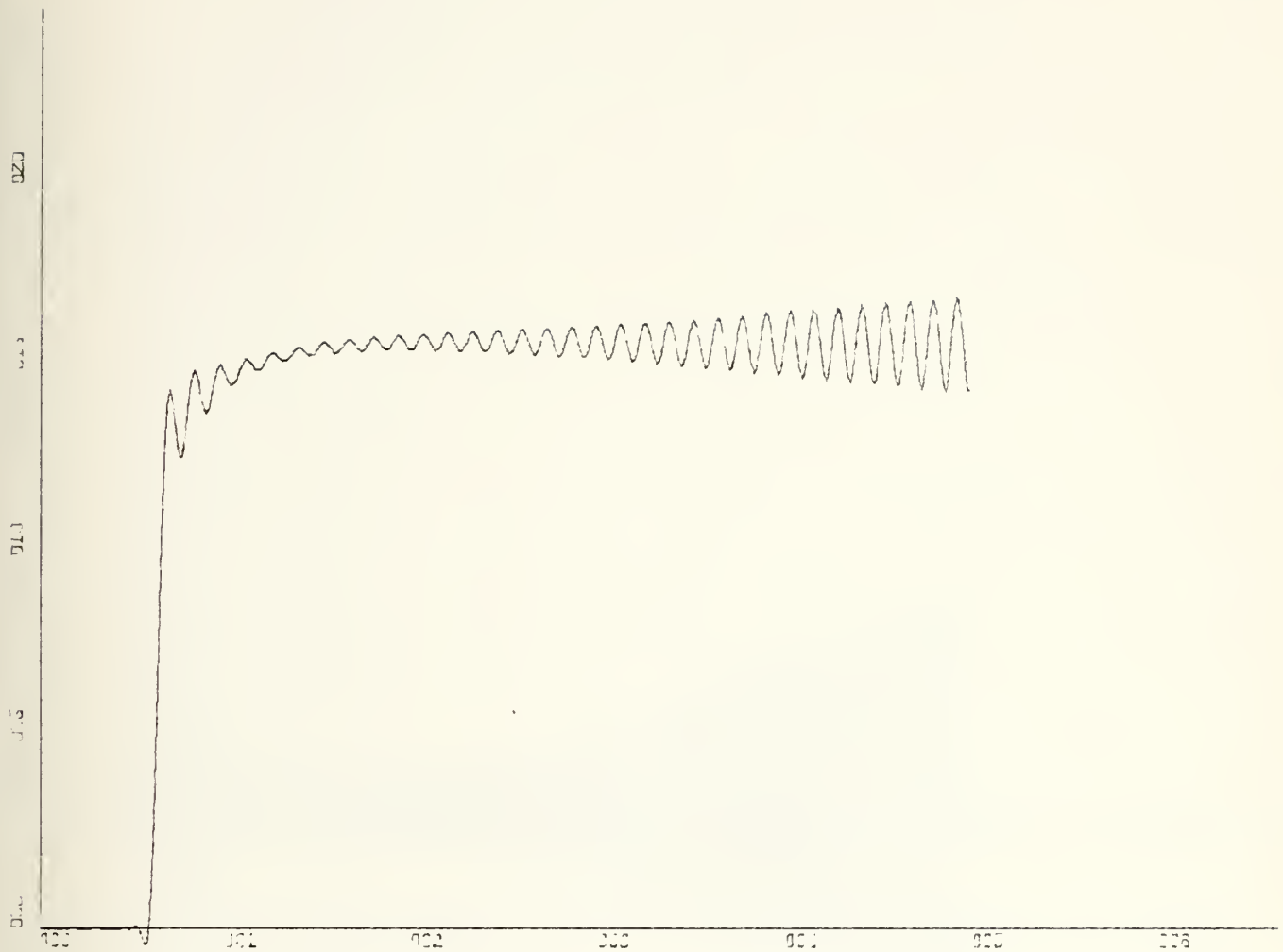
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-02 UNITS INCH.
RGR005 , TURN 20 KN , RUDM=15
PLOT IS PITCH RATE VERSUS TIME

PLOT 16

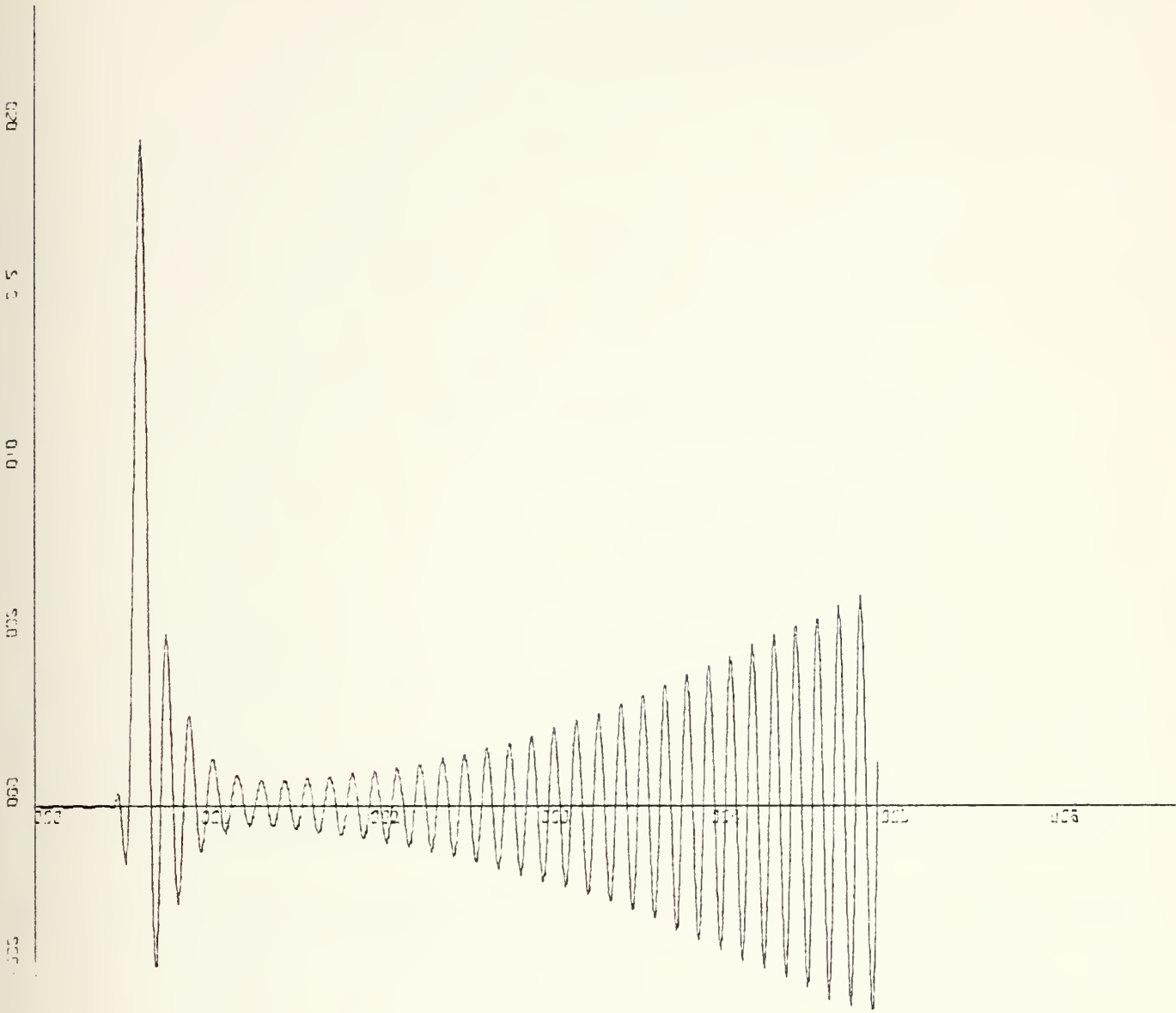
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROE5 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 17

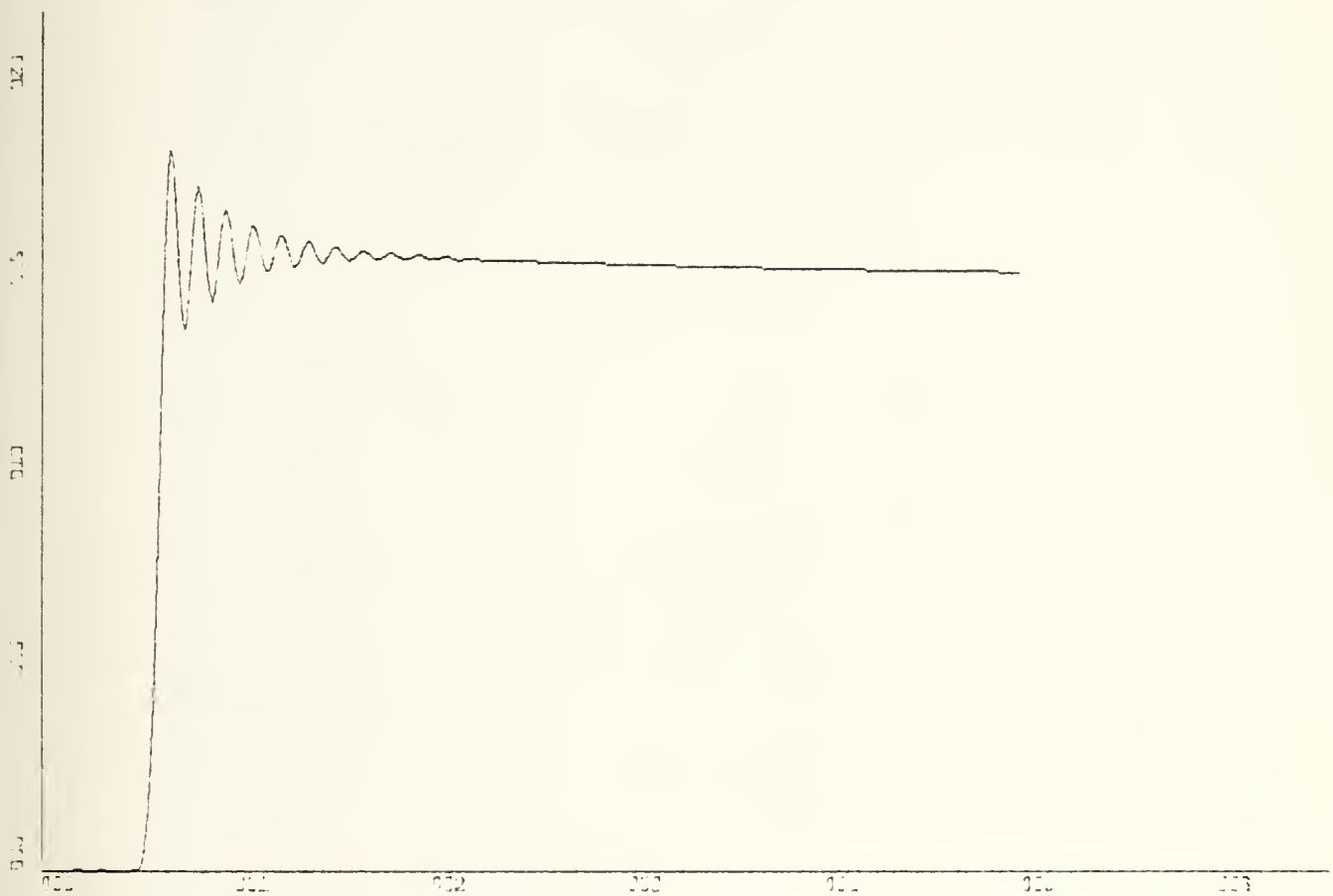
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROES , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL RATE VERSUS TIME

PLOT 18

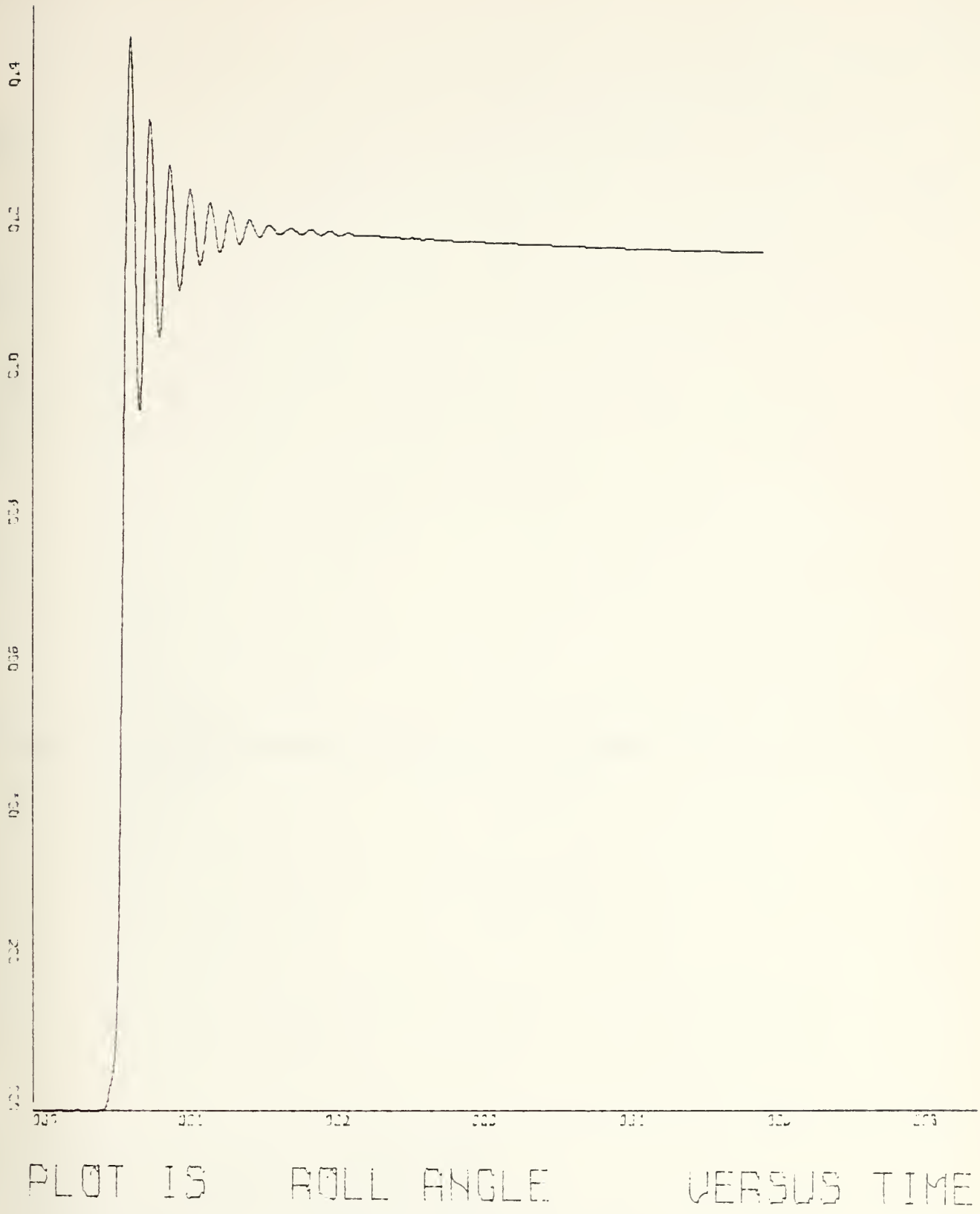
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGRT61 , TURN 20 kN.
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 19

for applied parameters see first page of this appendix

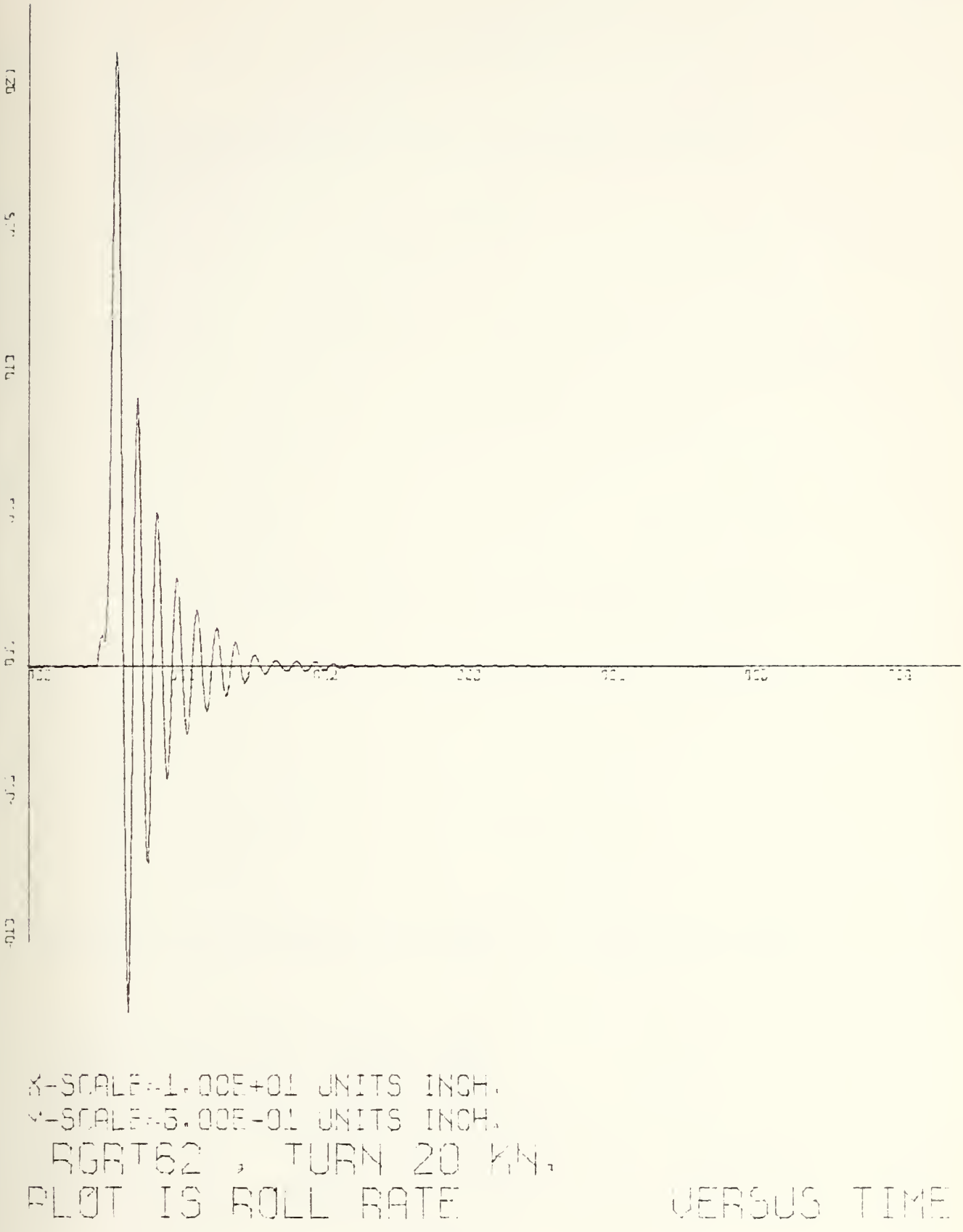


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE -1.00E+01 UNITS INCH.
Y-SCALE -2.00E-01 UNITS INCH.

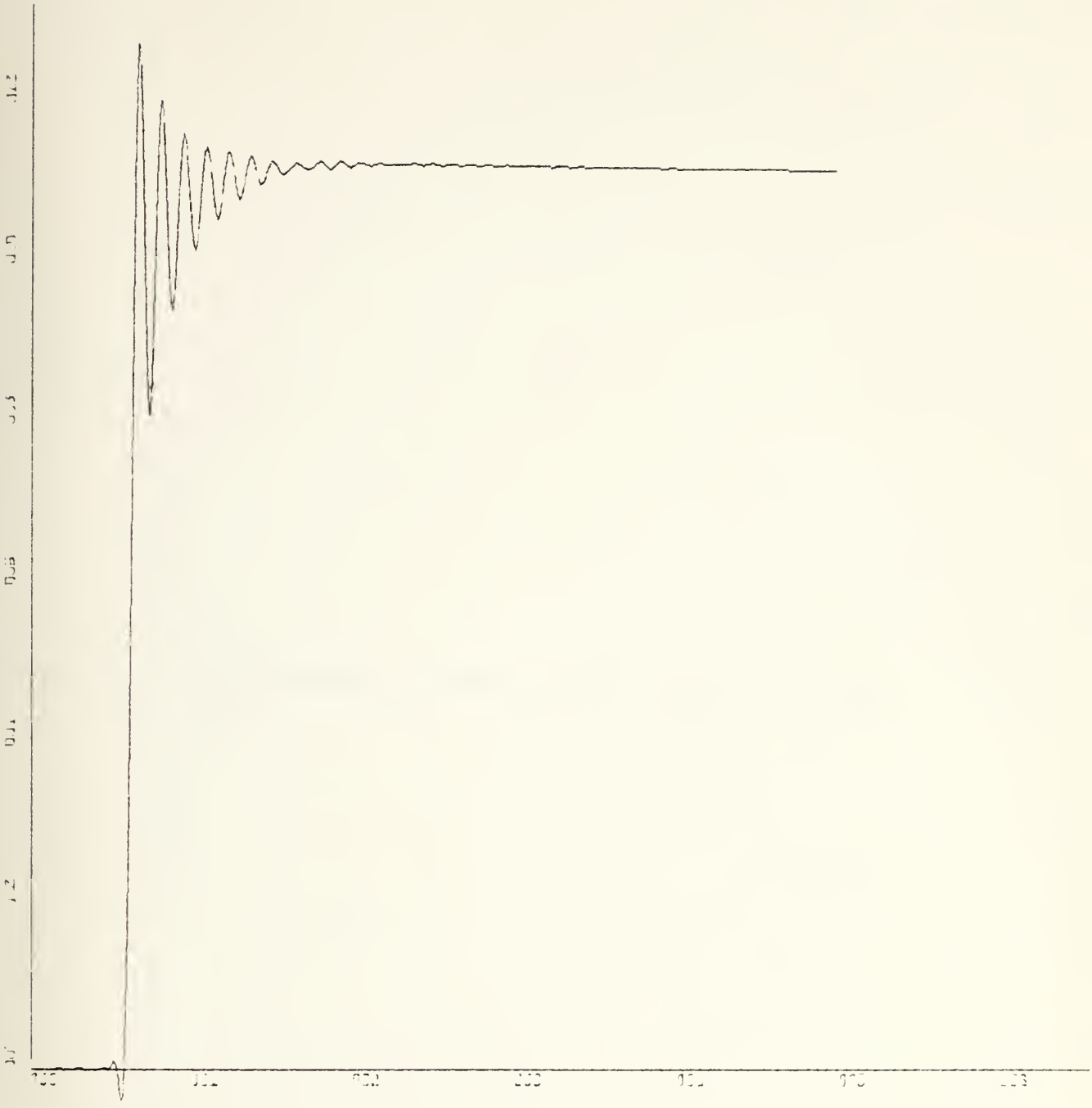
PLOT 21

for applied parameters see first page of this appendix



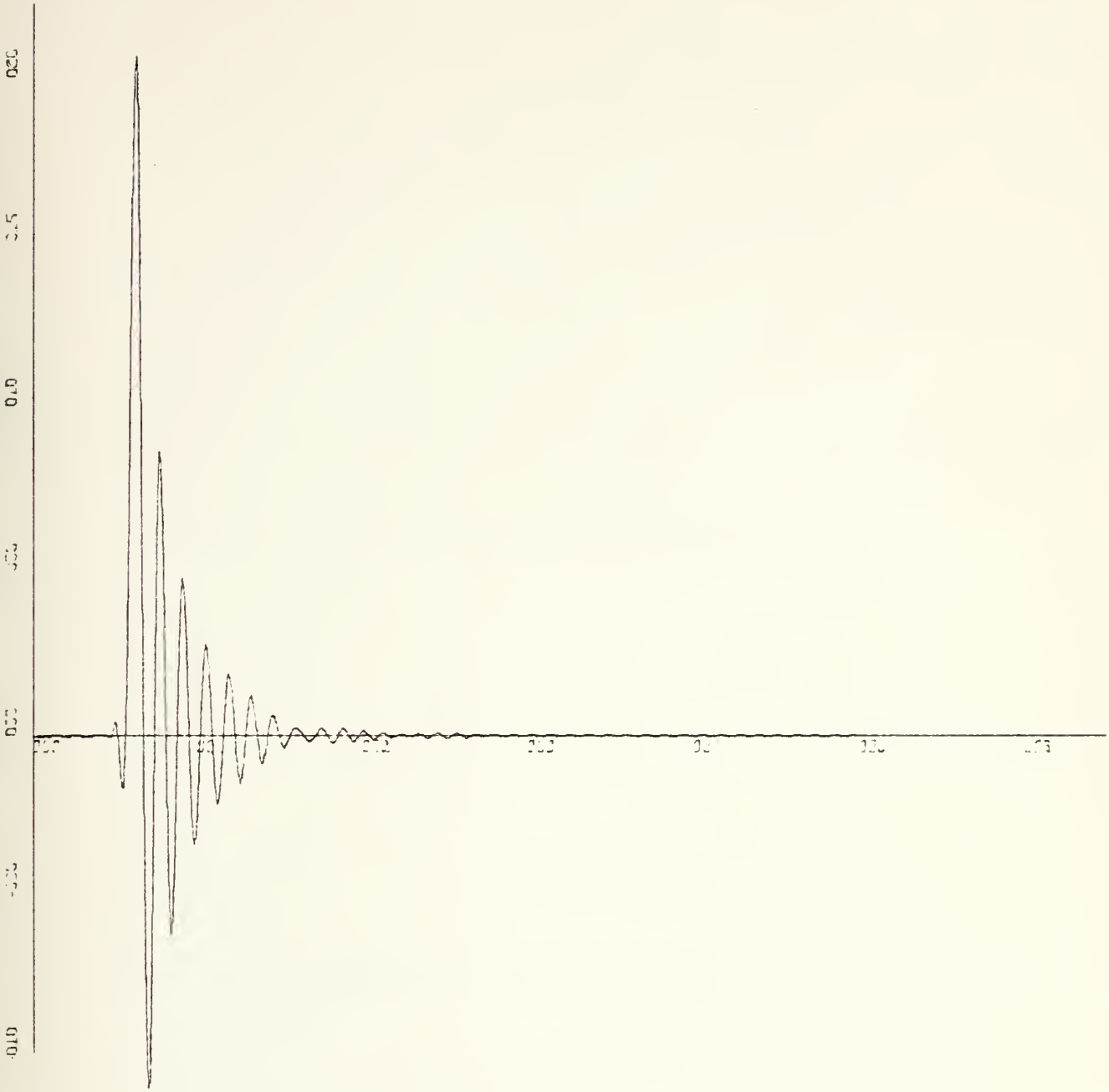
PLOT 22

for applied parameters see first page of this appendix



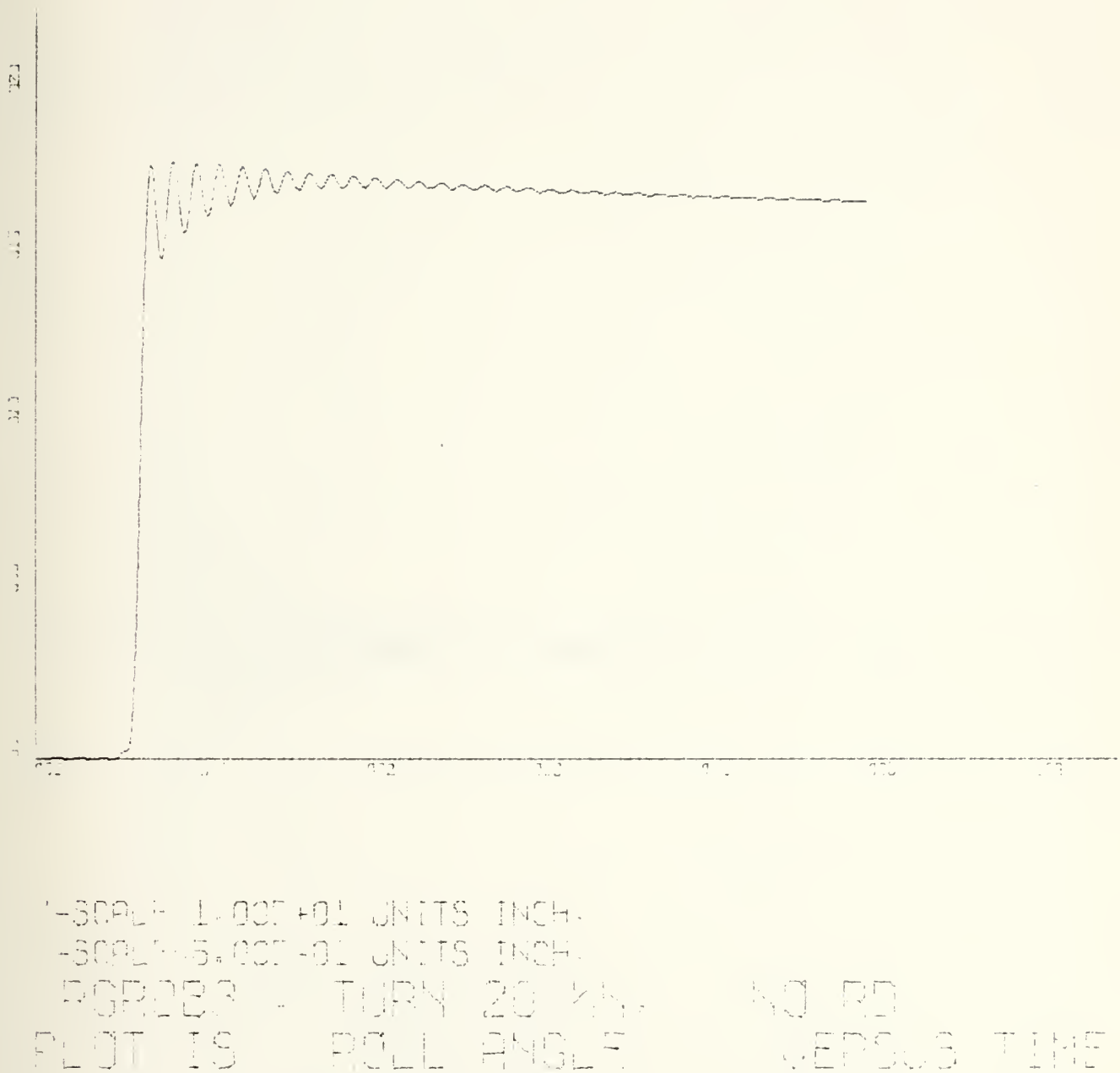
PLOT 23

for applied parameters see first page of this appendix



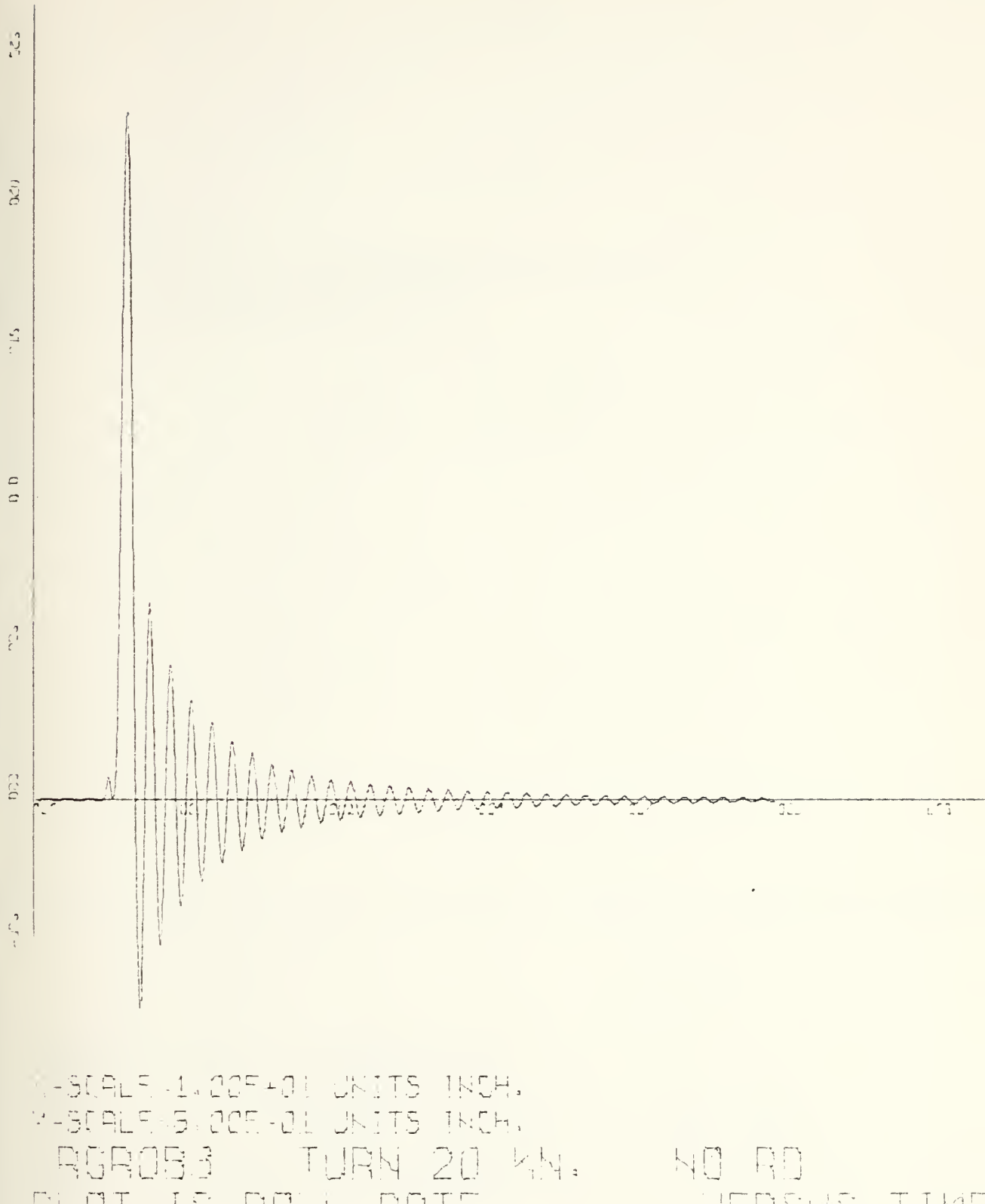
PLOT 24

for applied parameters see first page of this appendix



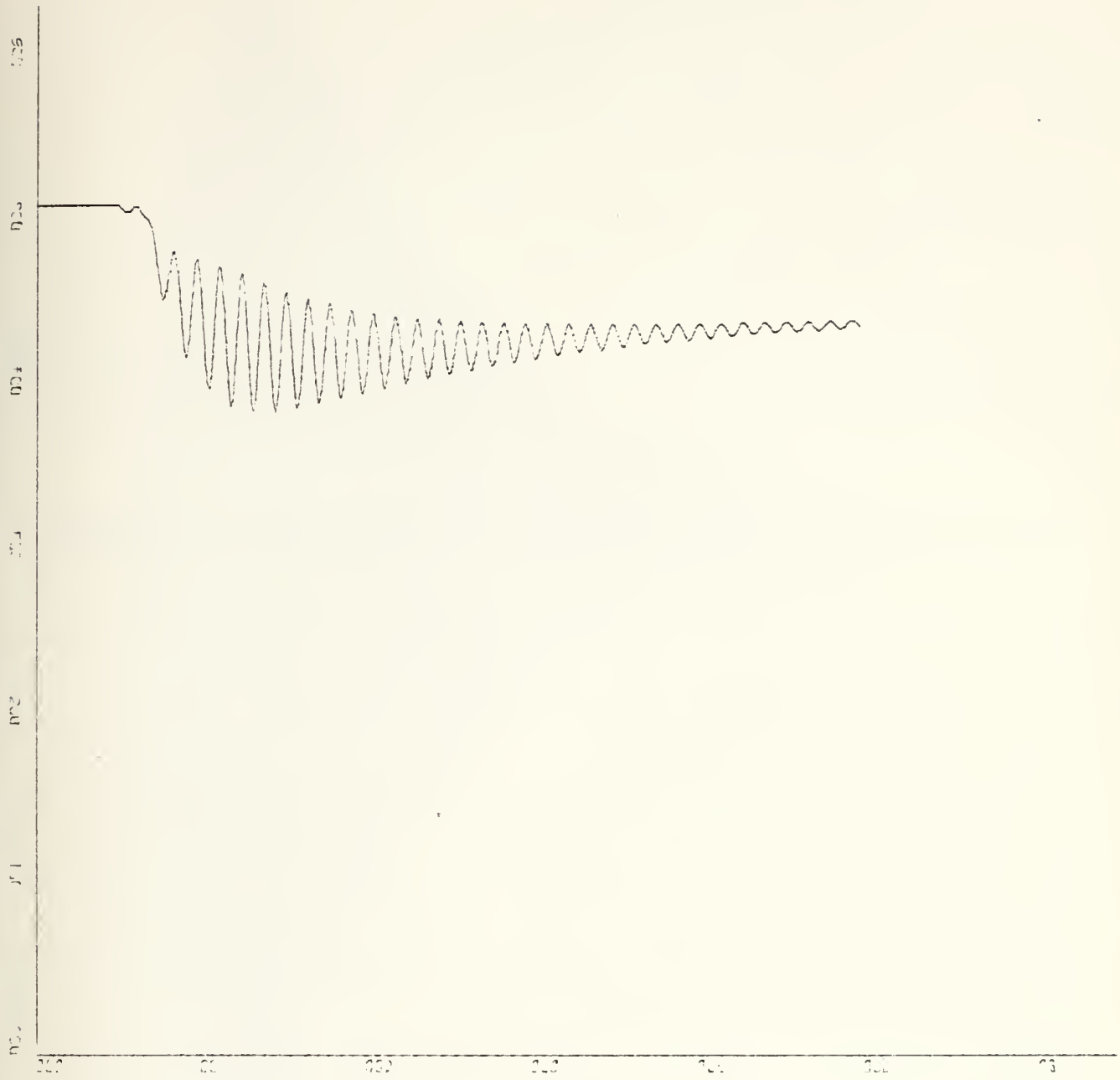
PLOT 25

for applied parameters, see first page of this appendix



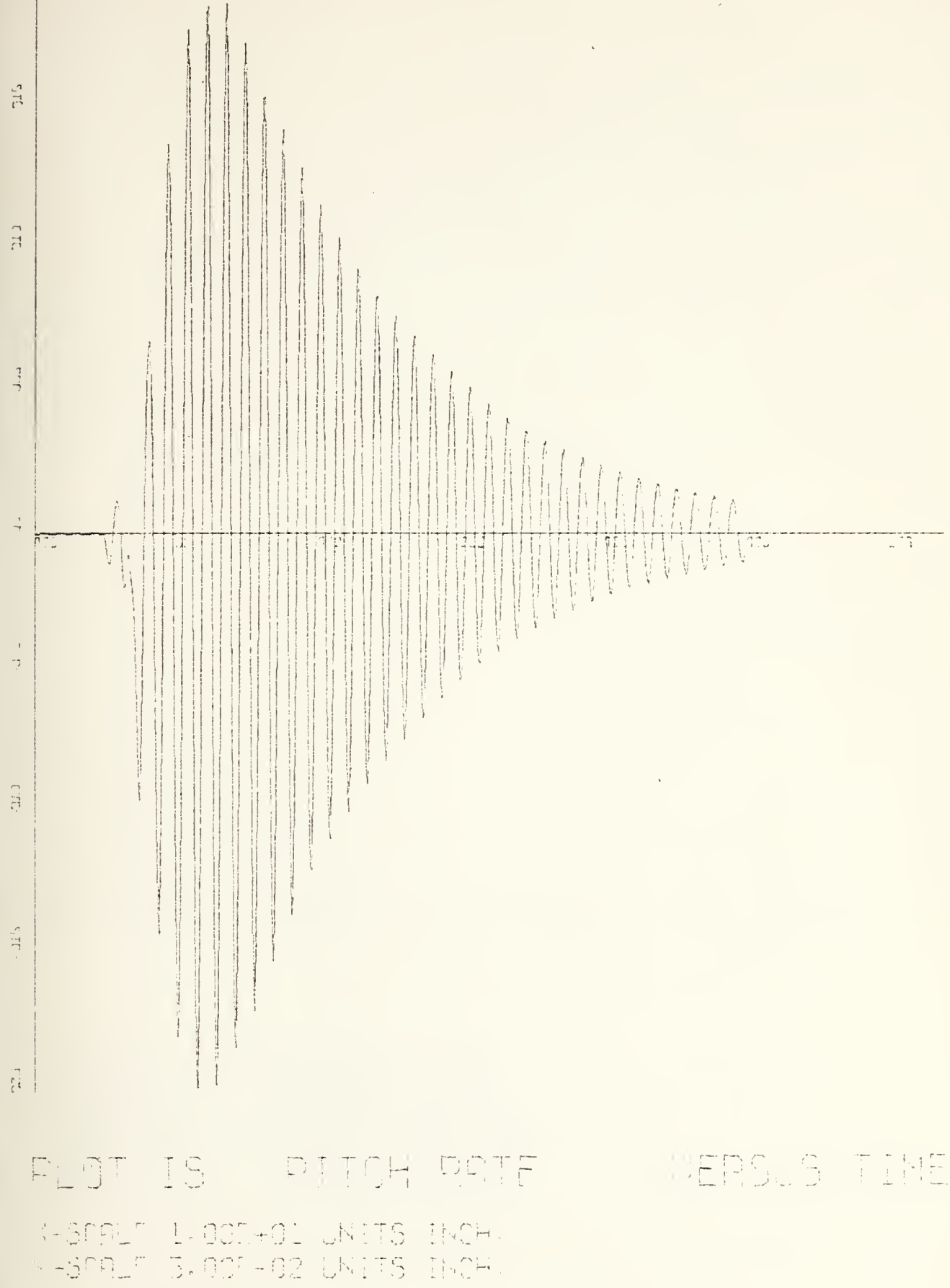
PLOT 26

for applied parameters see first page of this appendix



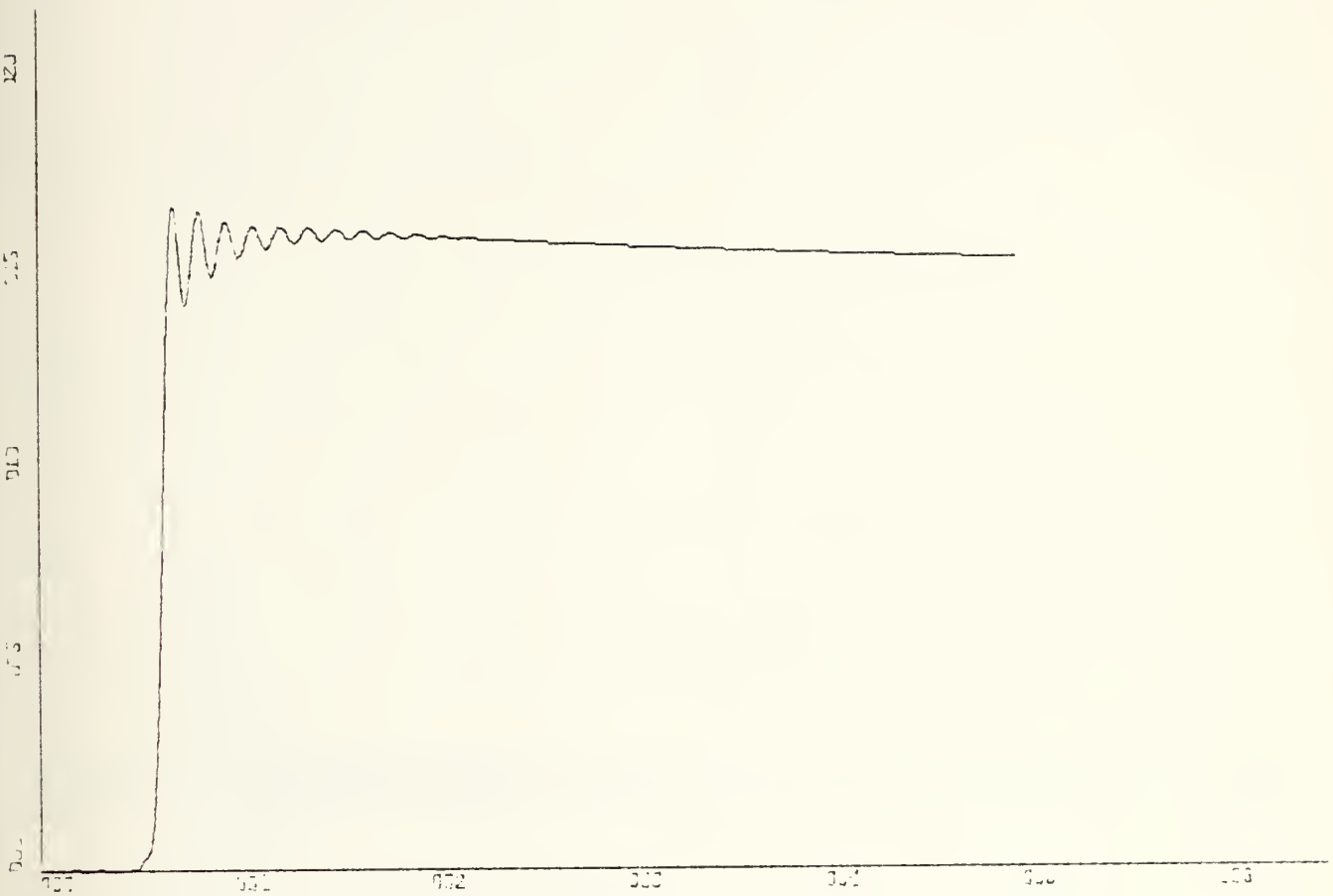
PLOT 27

for applied parameters see first page of this appendix



PLOT 28

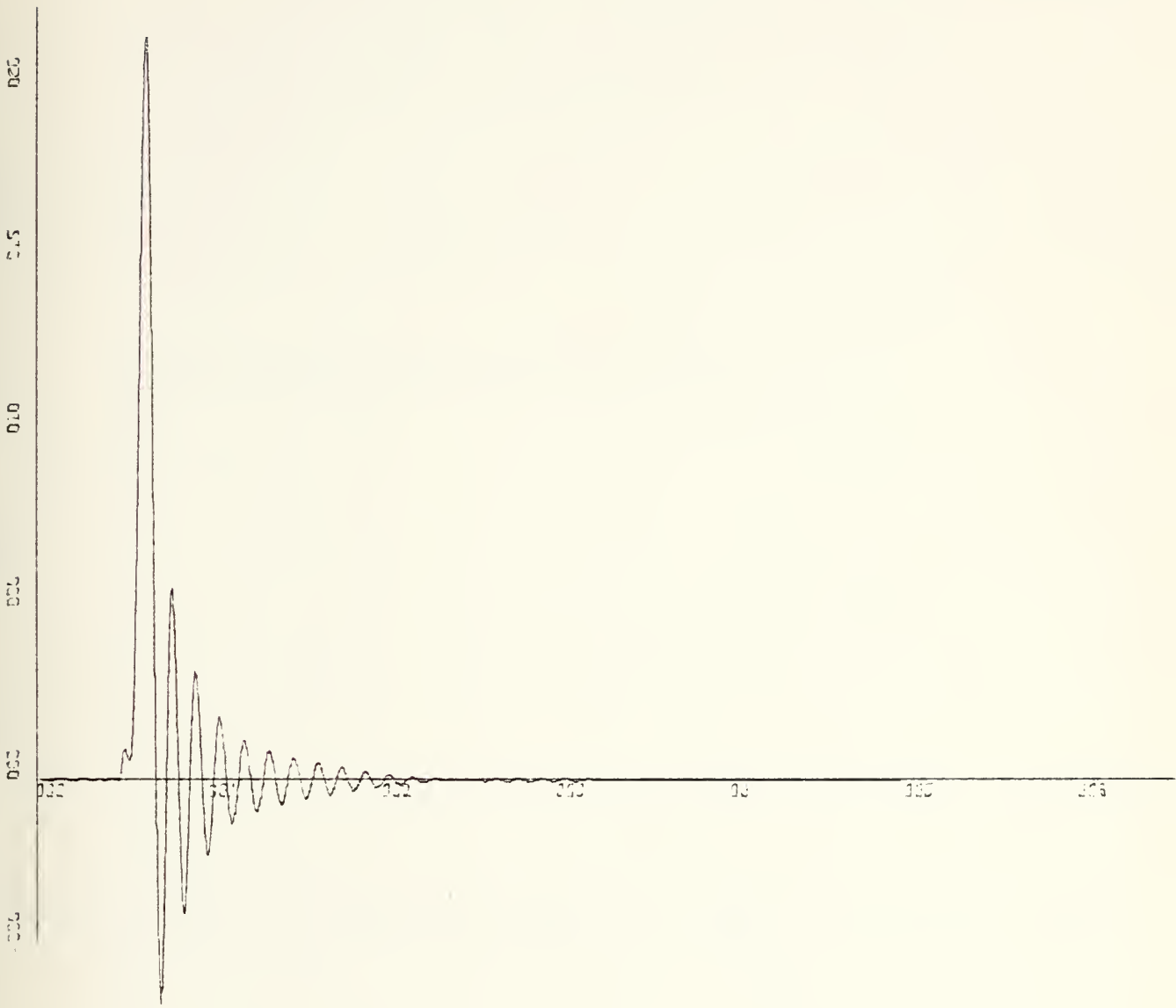
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=3.00E-01 UNITS INCH.
RGRT81 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

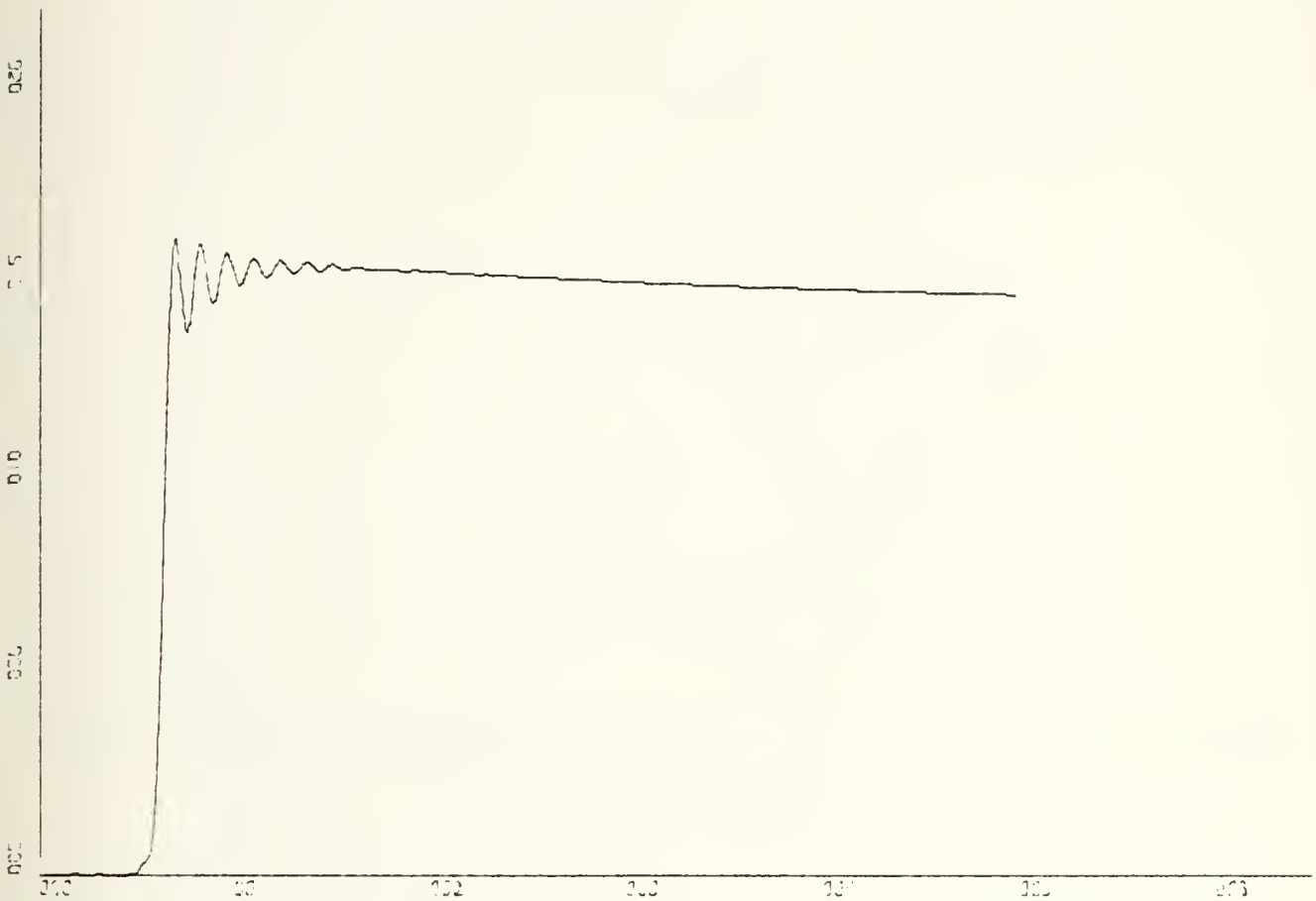
PLOT 29

for applied parameters see first page of this appendix



PLOT 30

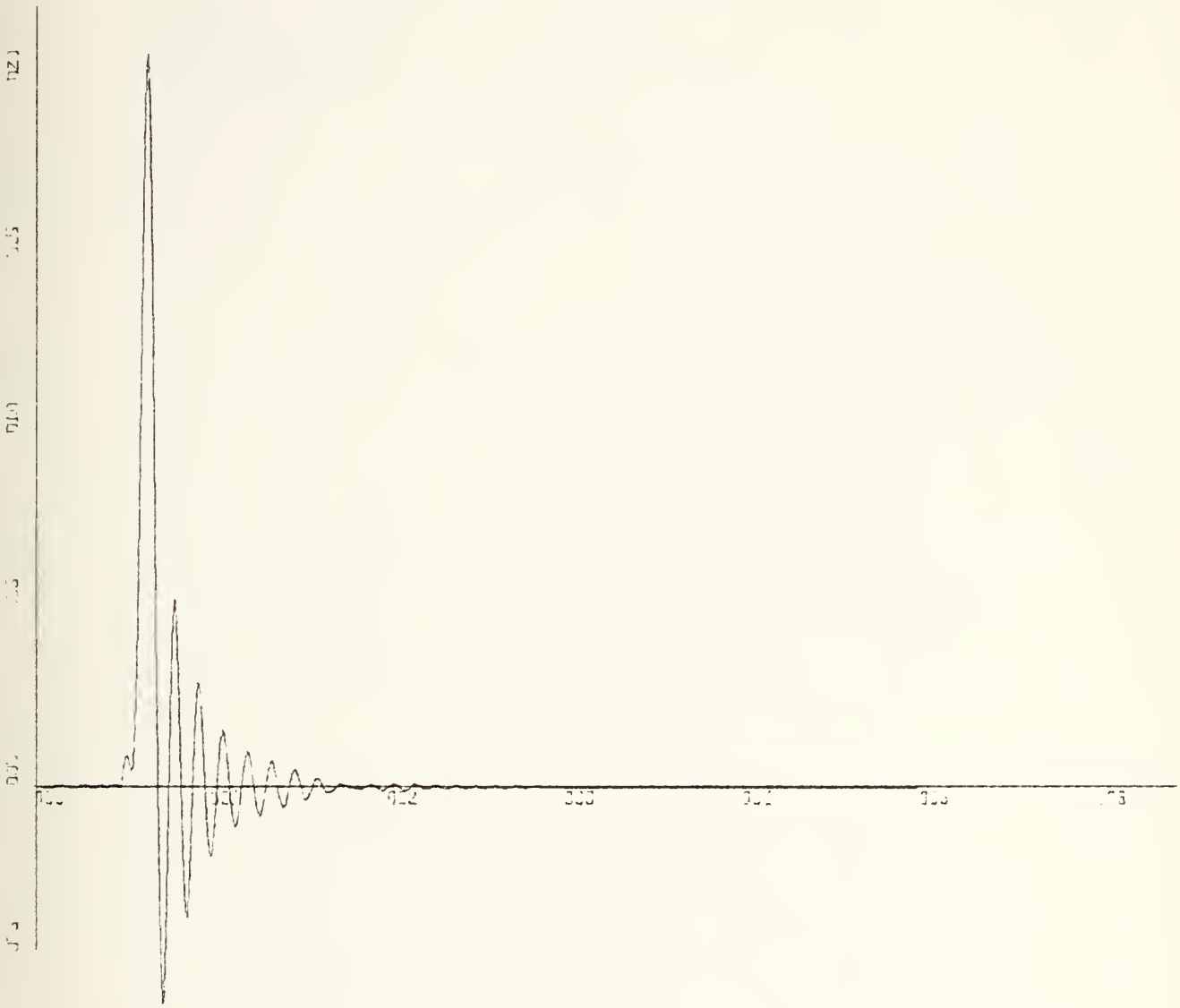
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGRT82 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

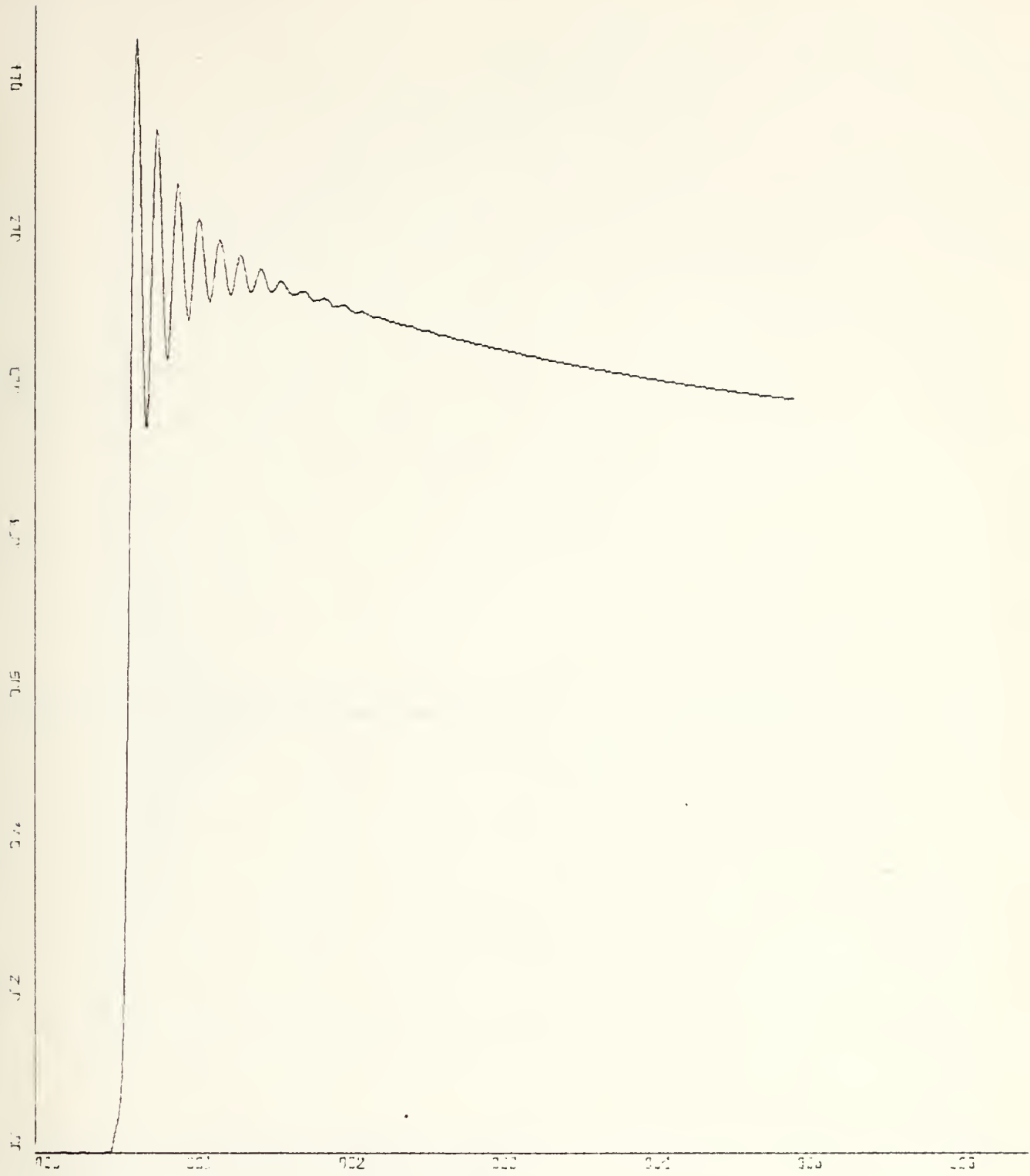
PLOT 31

for applied parameters see first page of this appendix



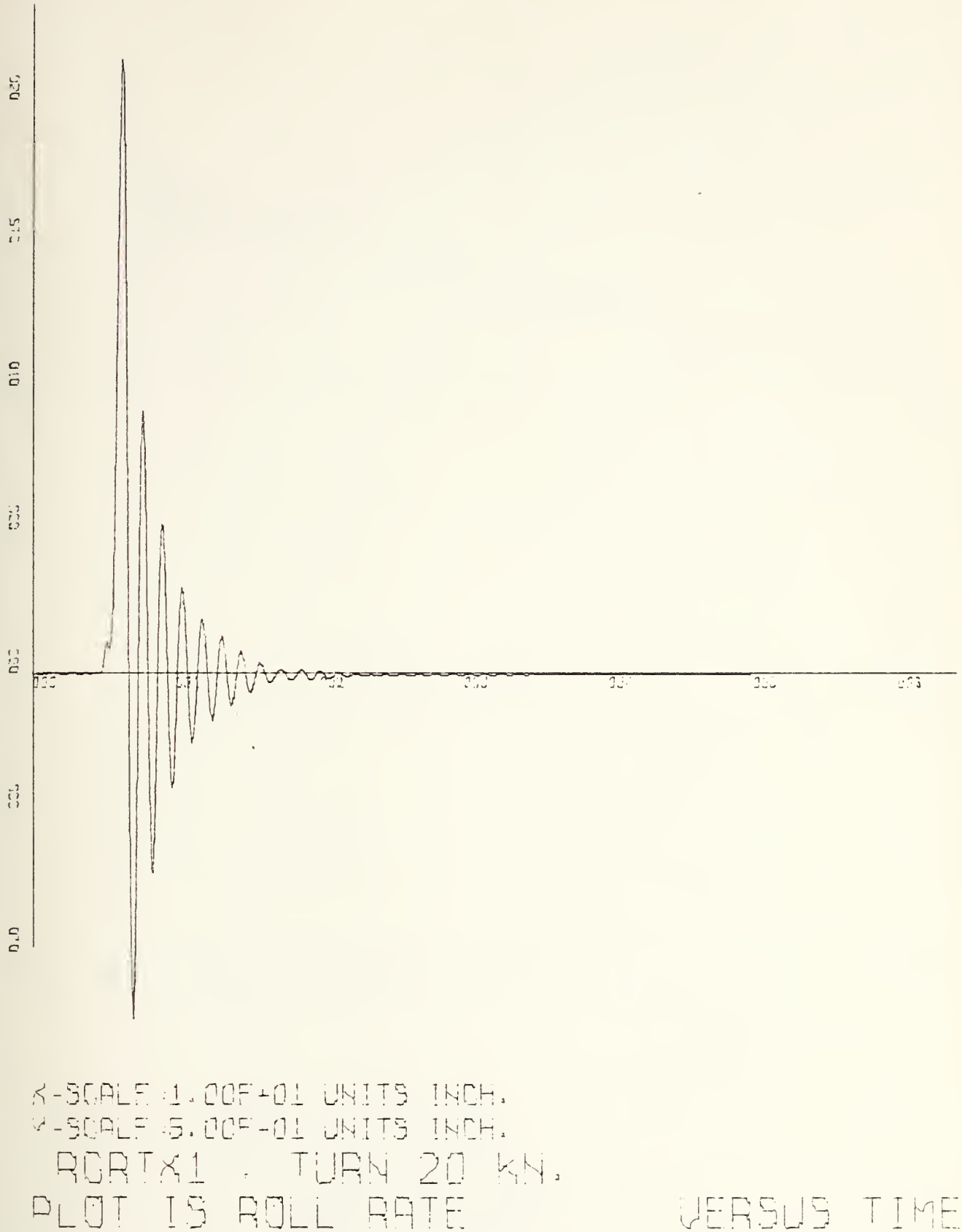
PLOT 32

for applied parameters see first page of this appendix



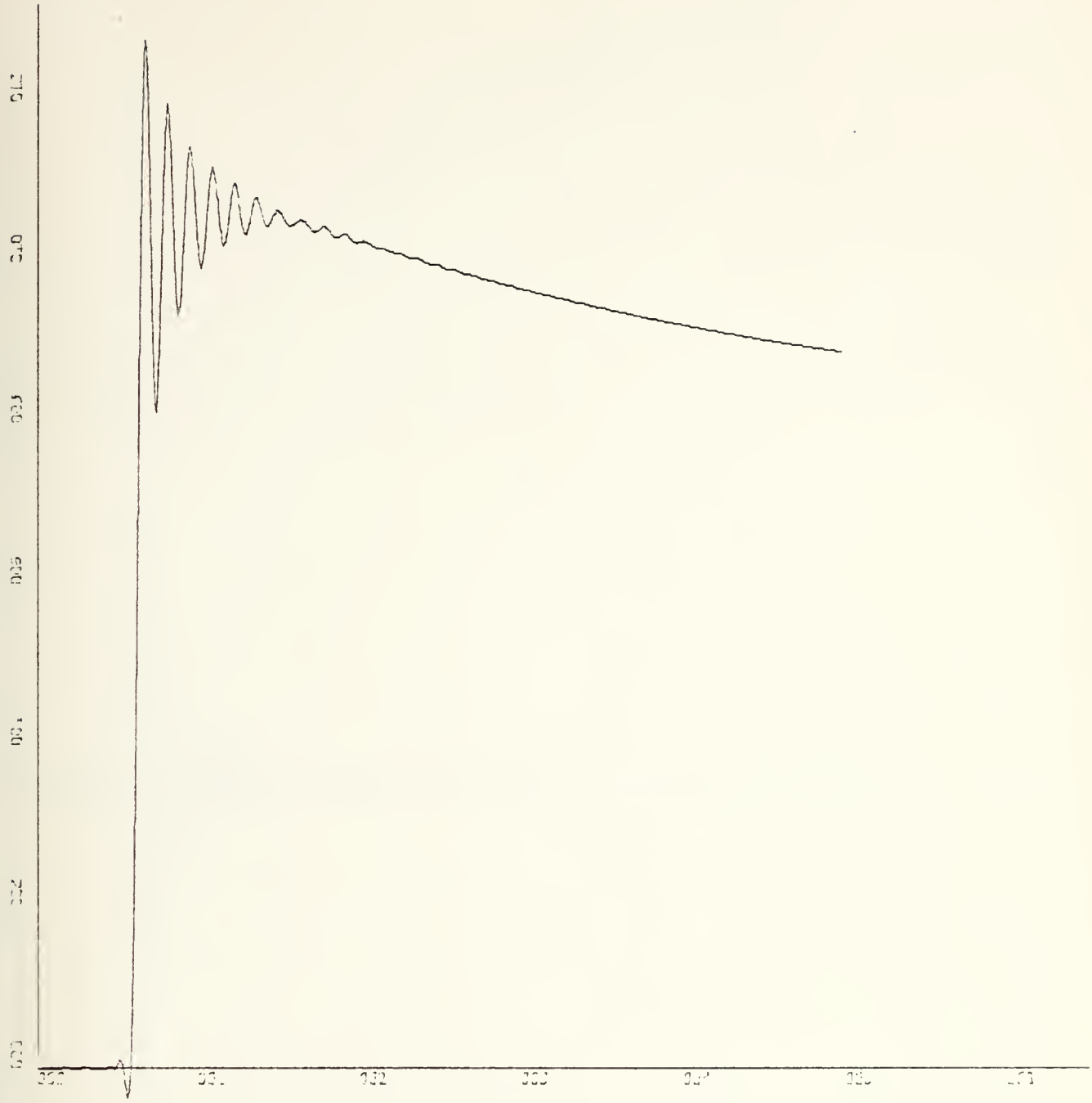
PLOT 33

for applied parameters see first page of this appendix



PLOT 34

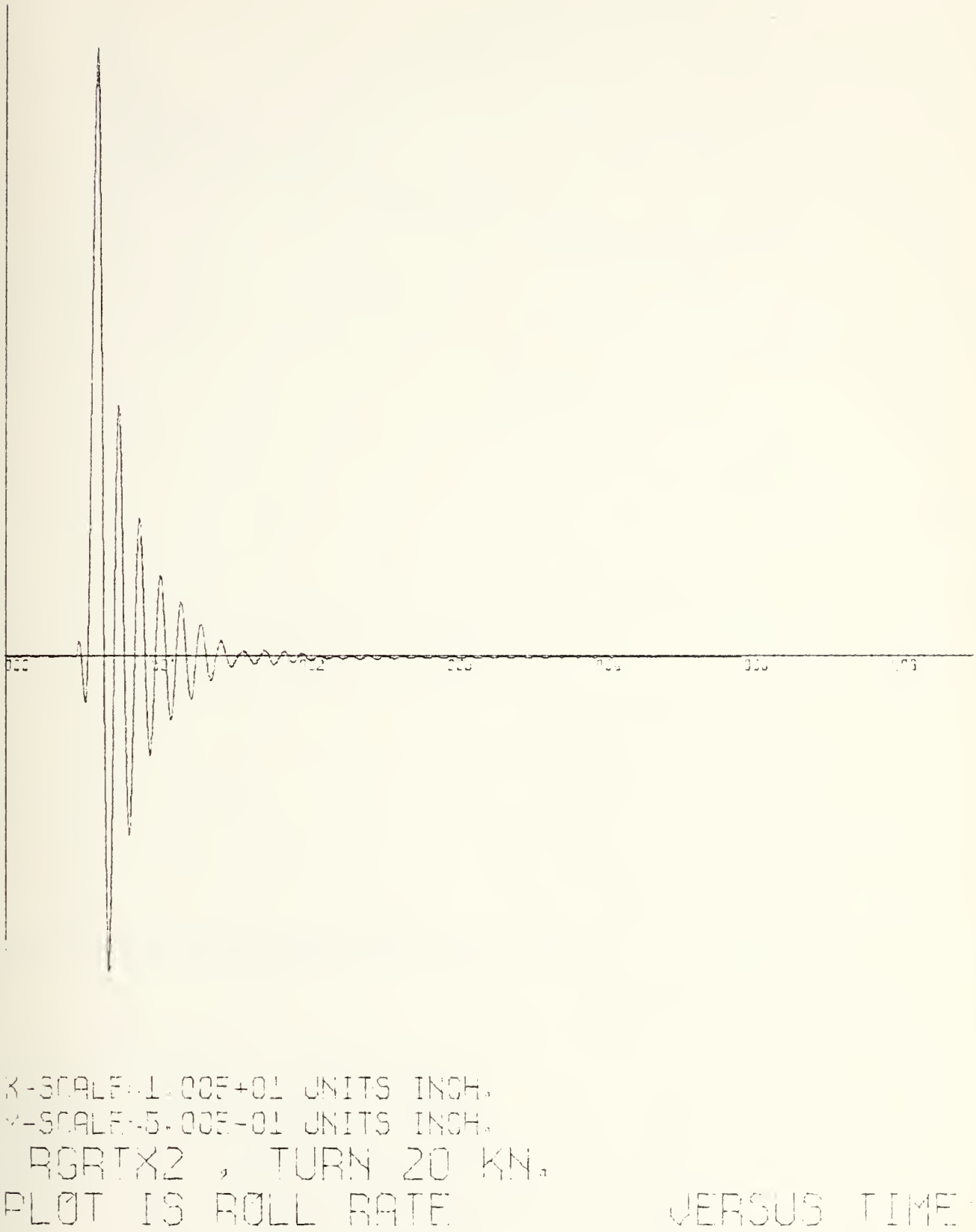
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.
RORTX2 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

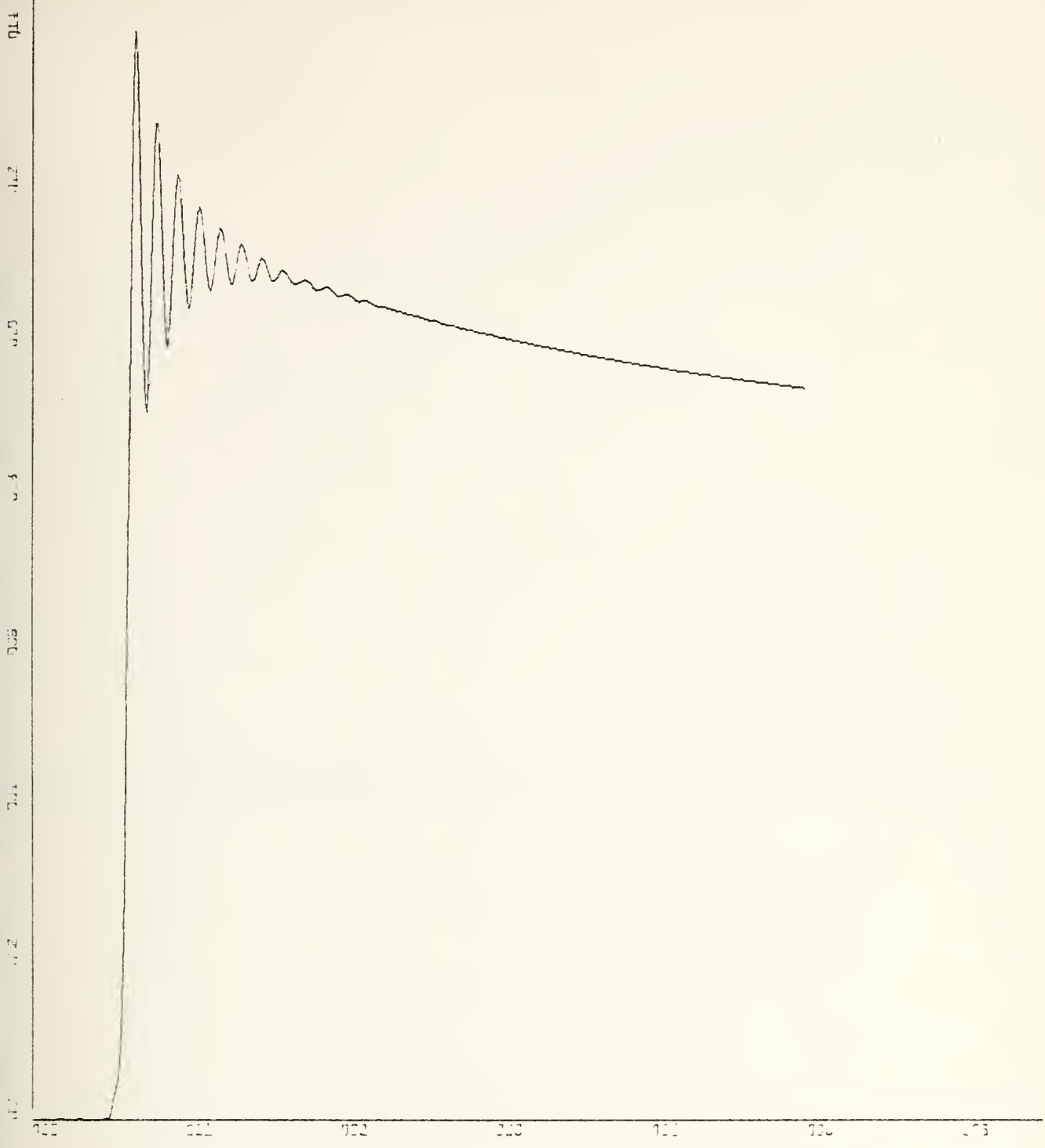
PLOT 35

for applied parameters see first page of this appendix



PLOT 36

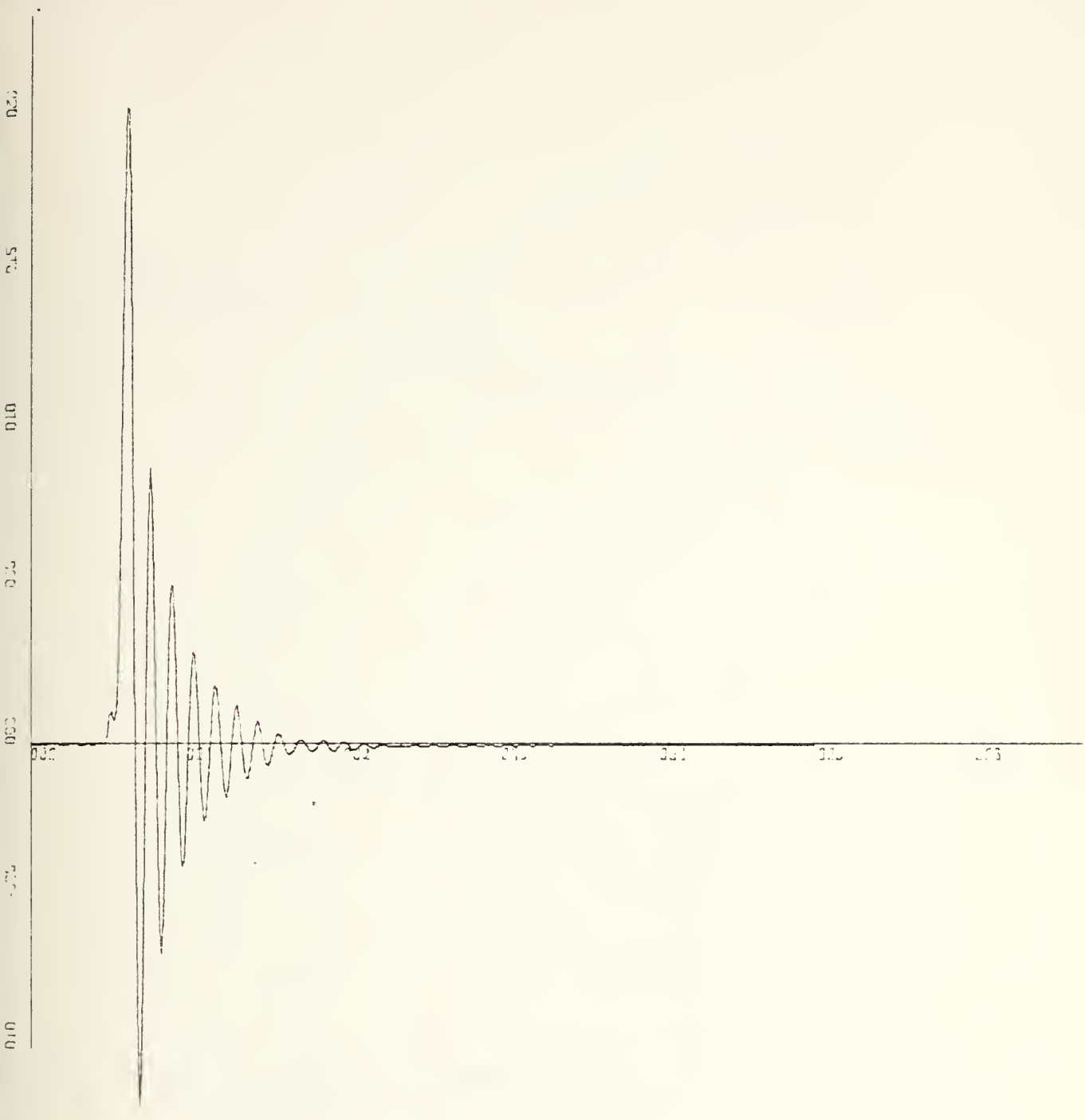
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.
RGRTX3 - TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

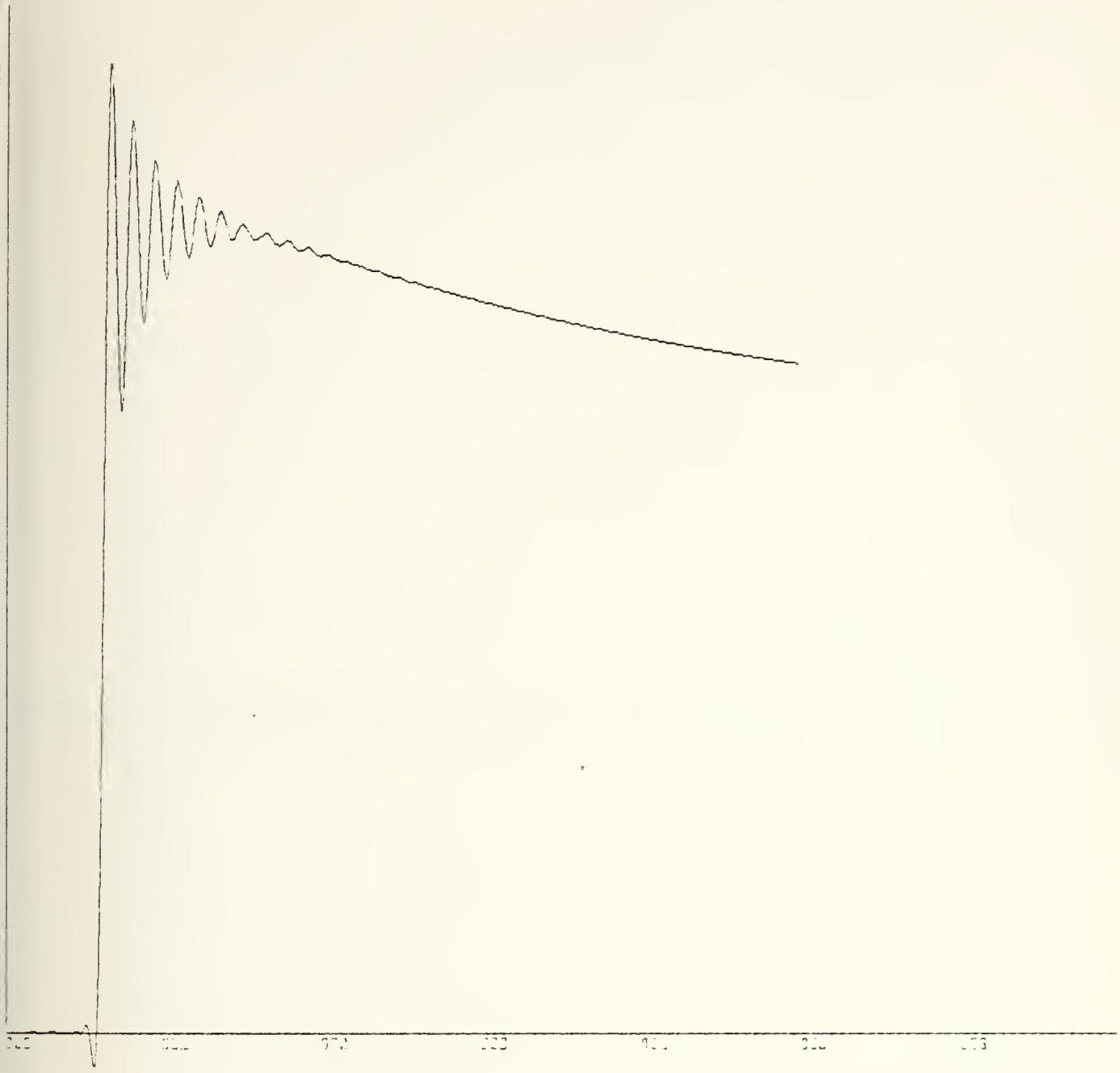
PLOT 37

for applied parameters see first page of this appendix



PLOT 38

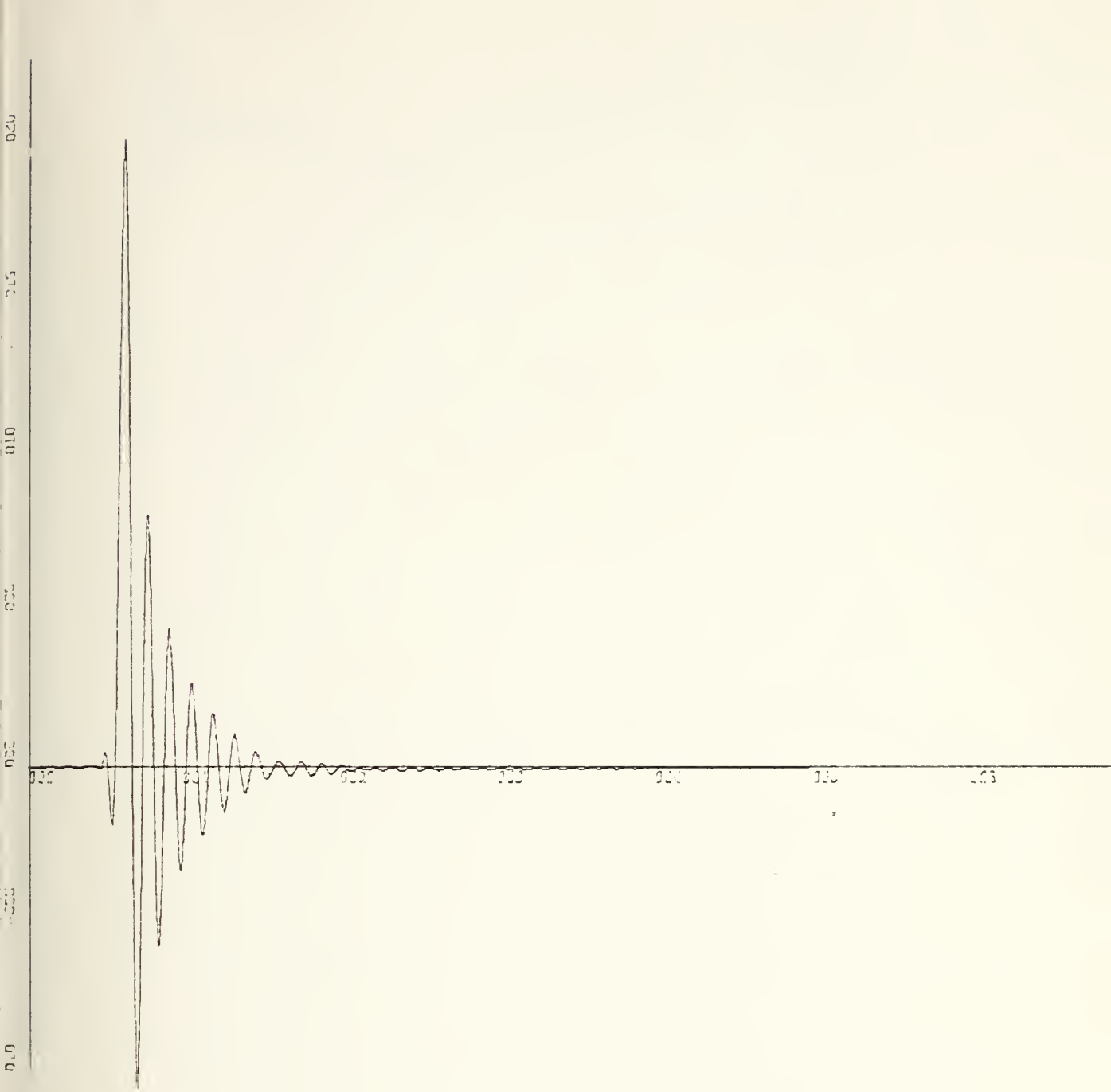
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.
AGRTX4 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

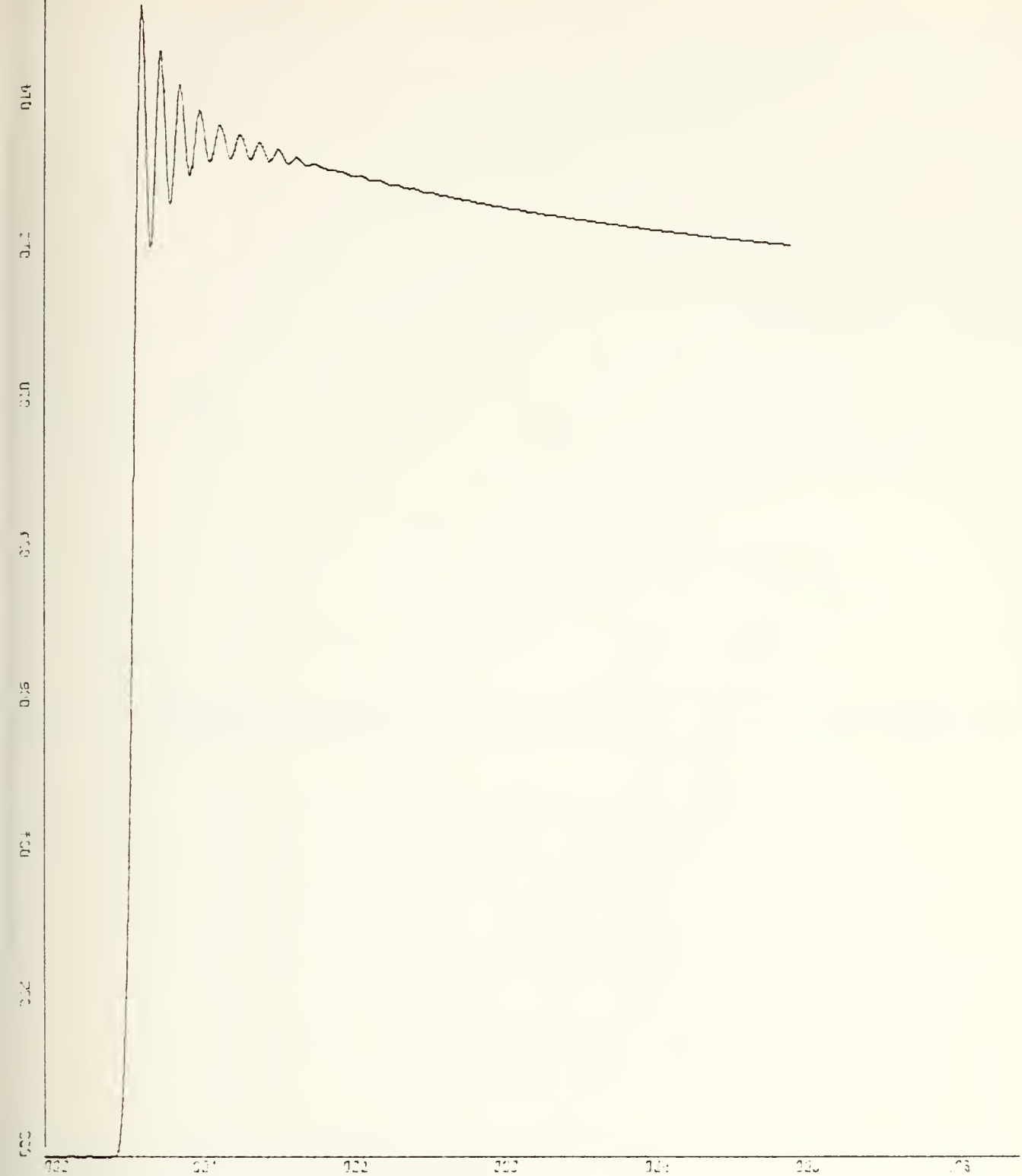
PLOT 39

for applied parameters see first page of this appendix



PLOT 40

for applied parameters see first page of this appendix

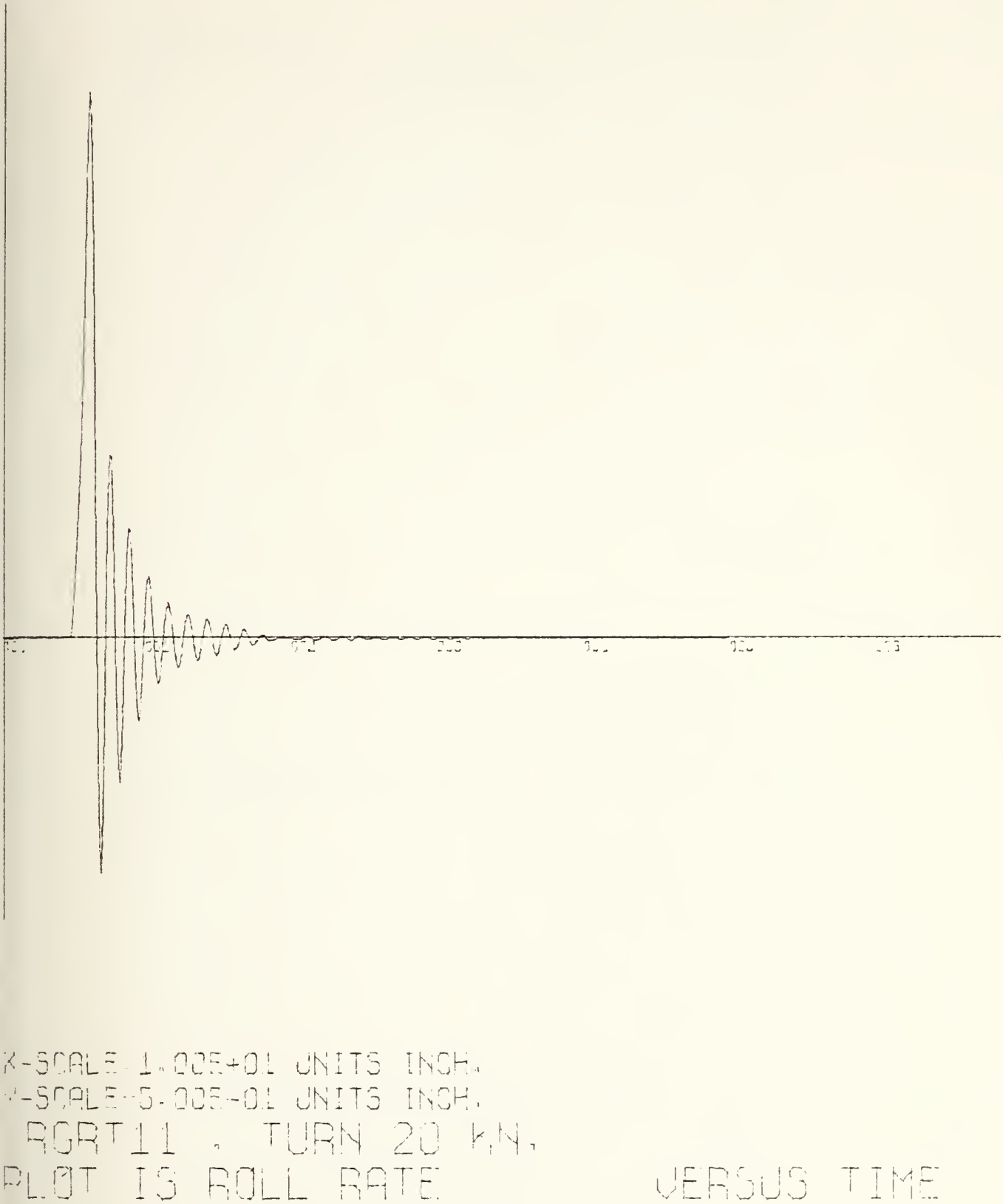


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

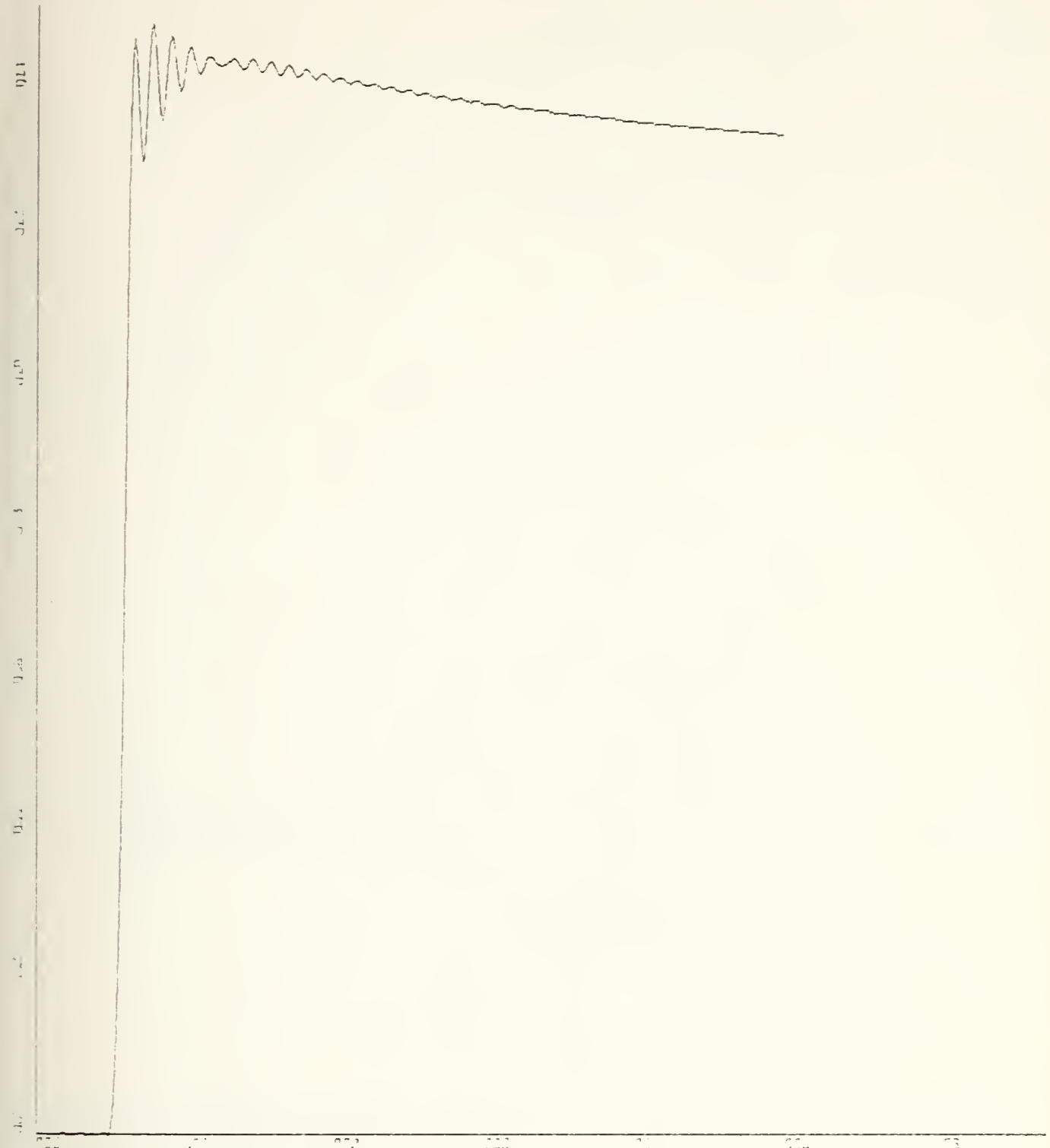
PLOT 41

for applied parameters see first page of this appendix



PLOT 42

for applied parameters see first page of this appendix

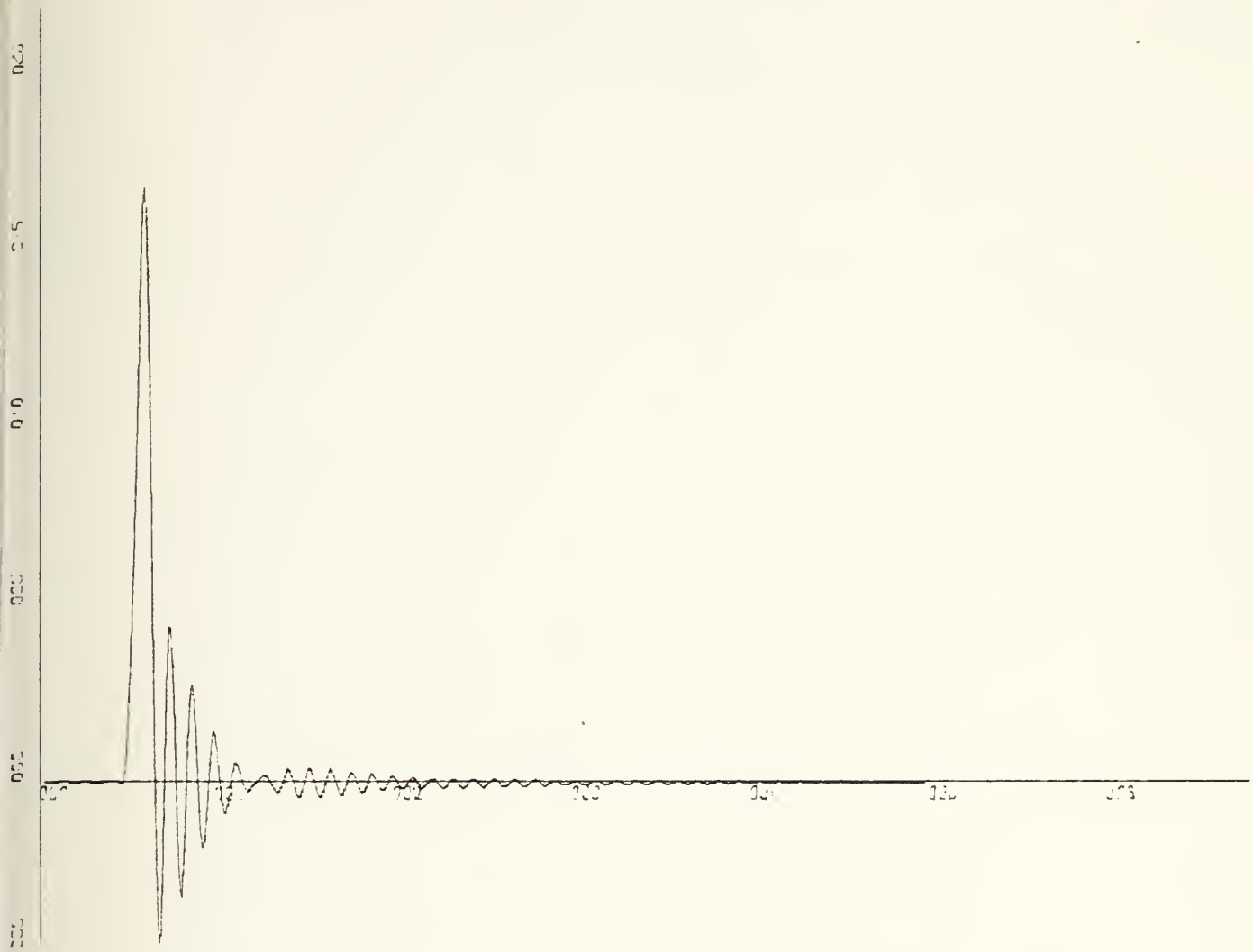


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 43

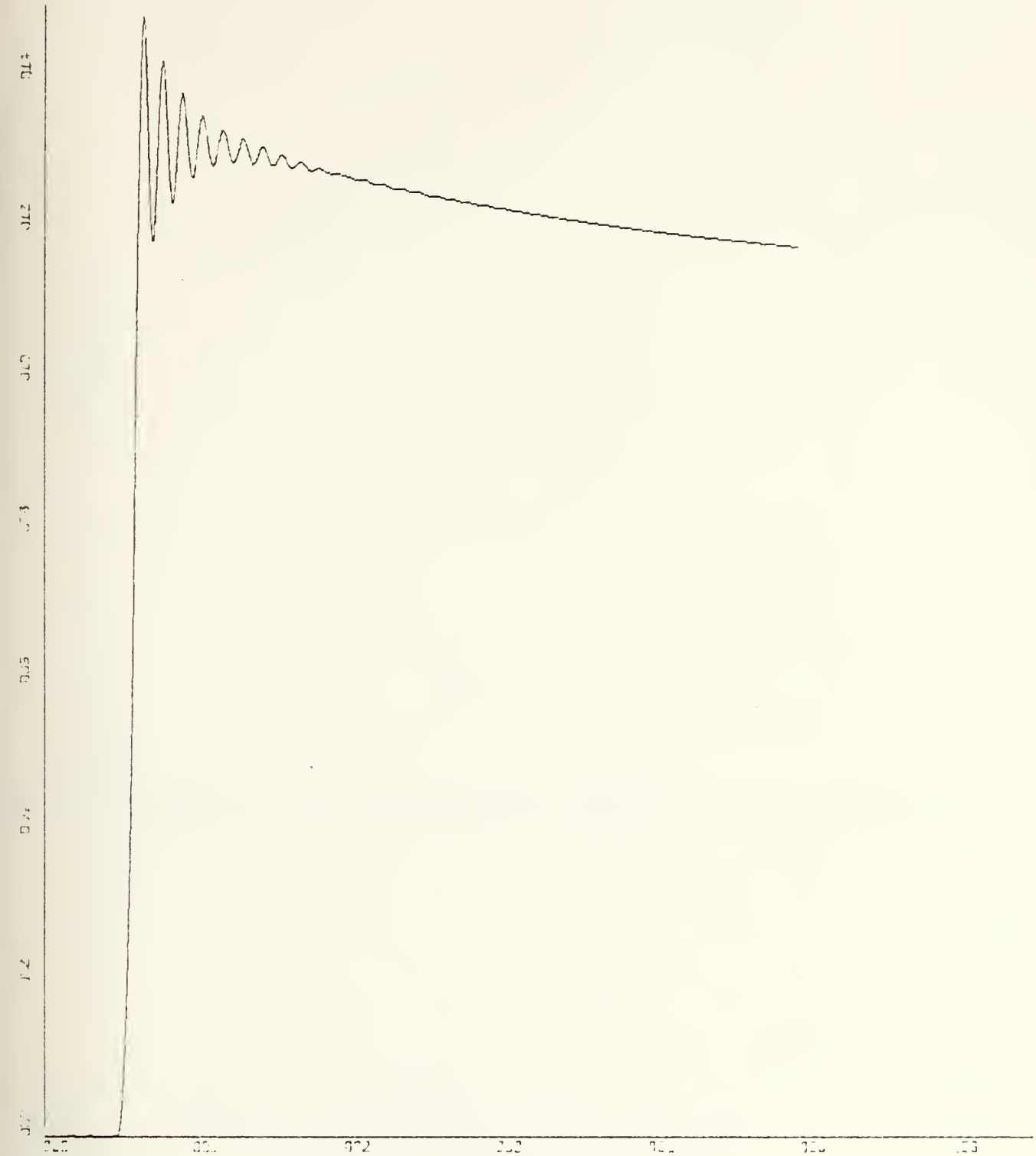
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
AGRT12 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 44

for applied parameters see first page of this appendix

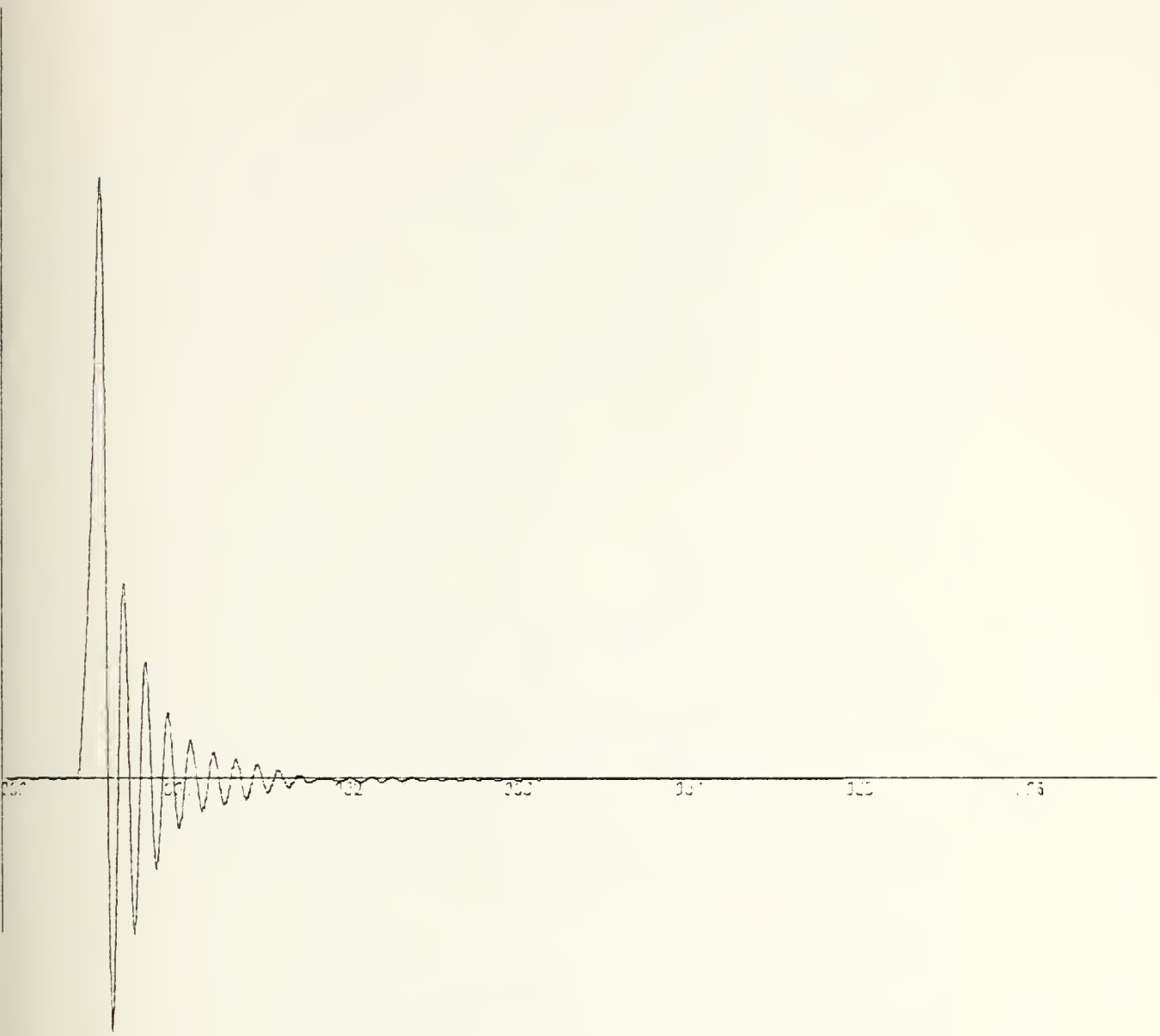


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 45

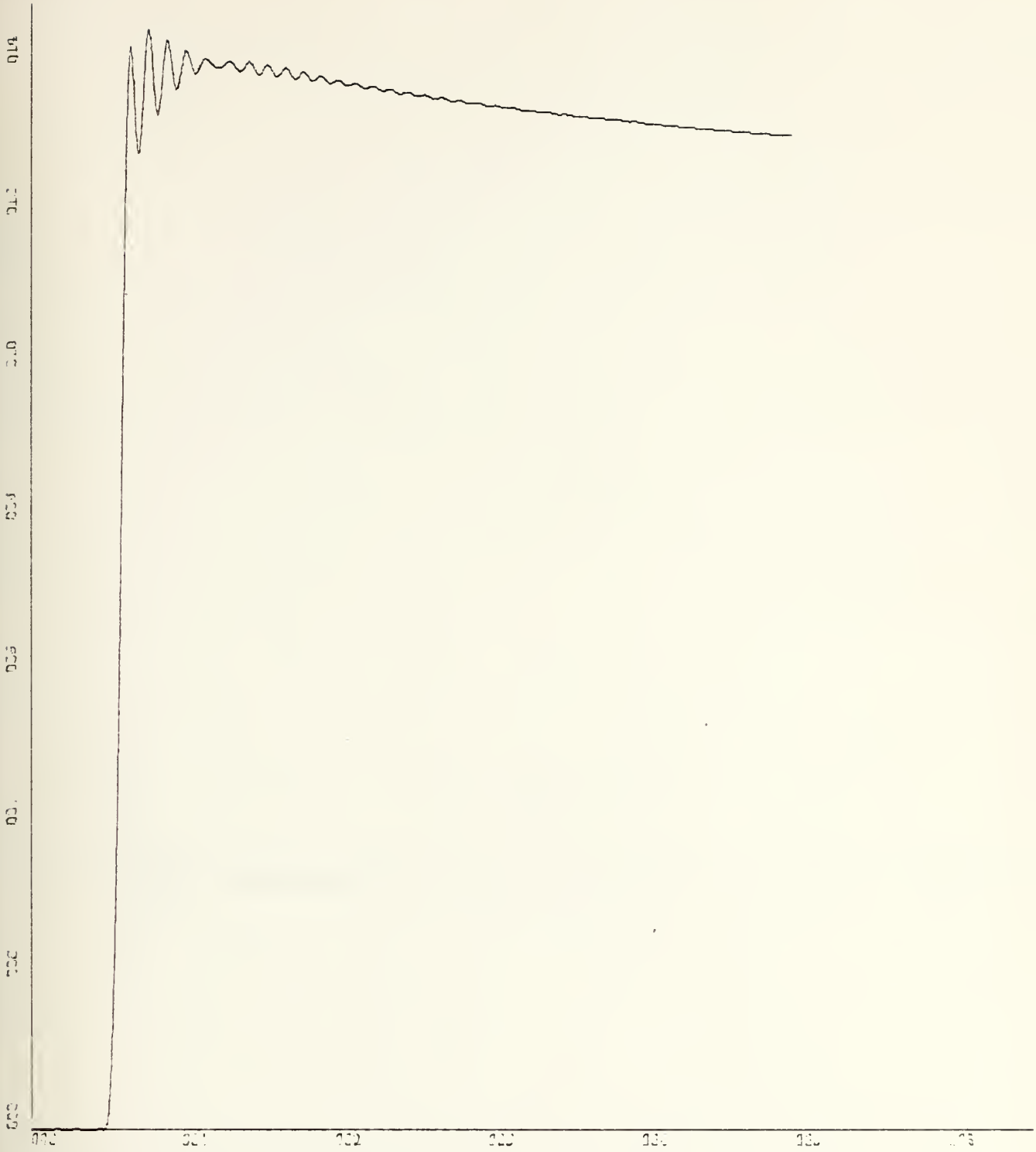
for applied parameters see first page of this appendix



X-SCALE=1.000+01 UNITS INCH.
Y-SCALE=5.000-01 UNITS INCH.
RORT13 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 46

for applied parameters see first page of this appendix

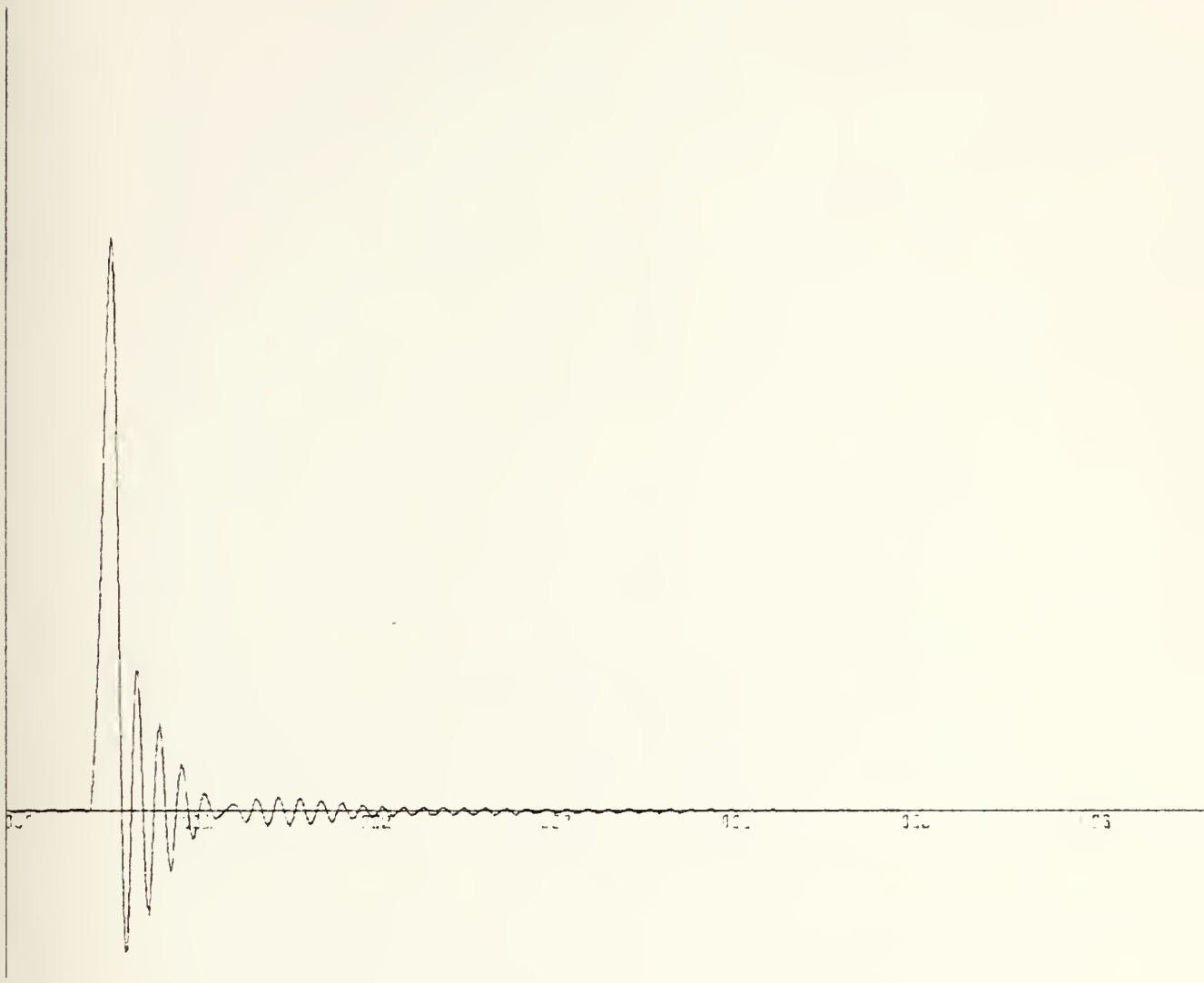


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 47

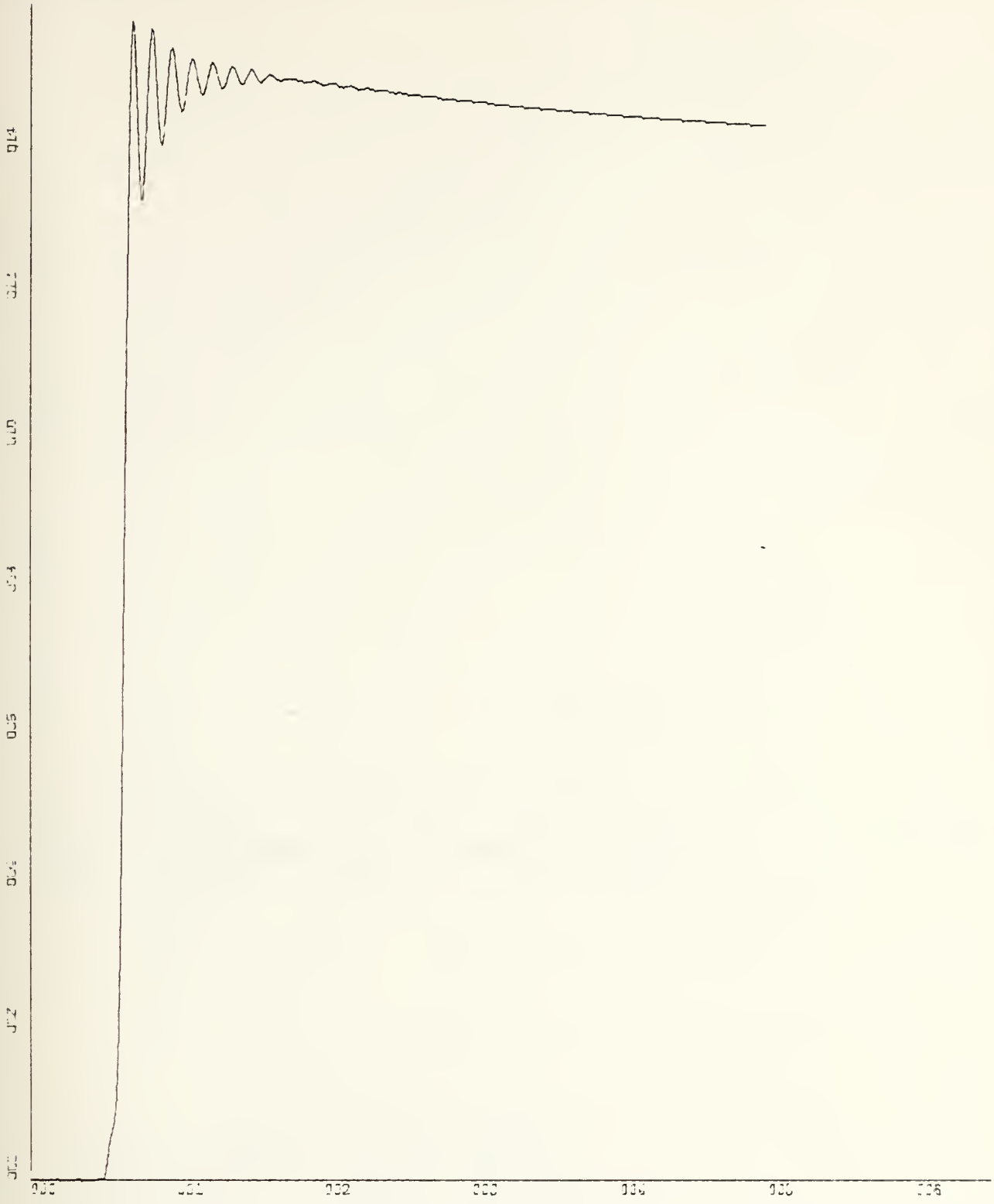
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
AGRT14 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 48

for applied parameters see first page of this appendix

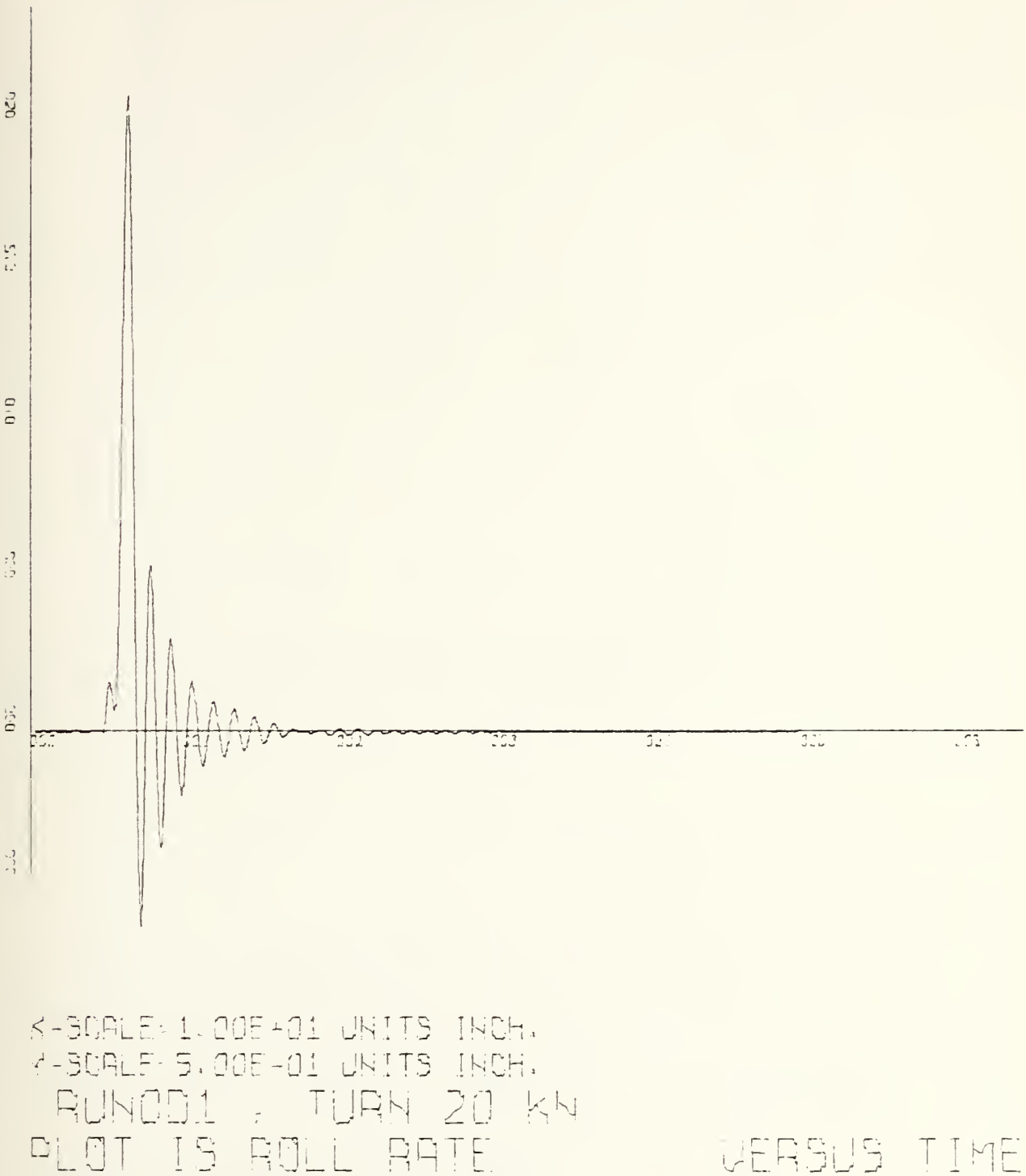


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 2.00E-01 UNITS INCH.

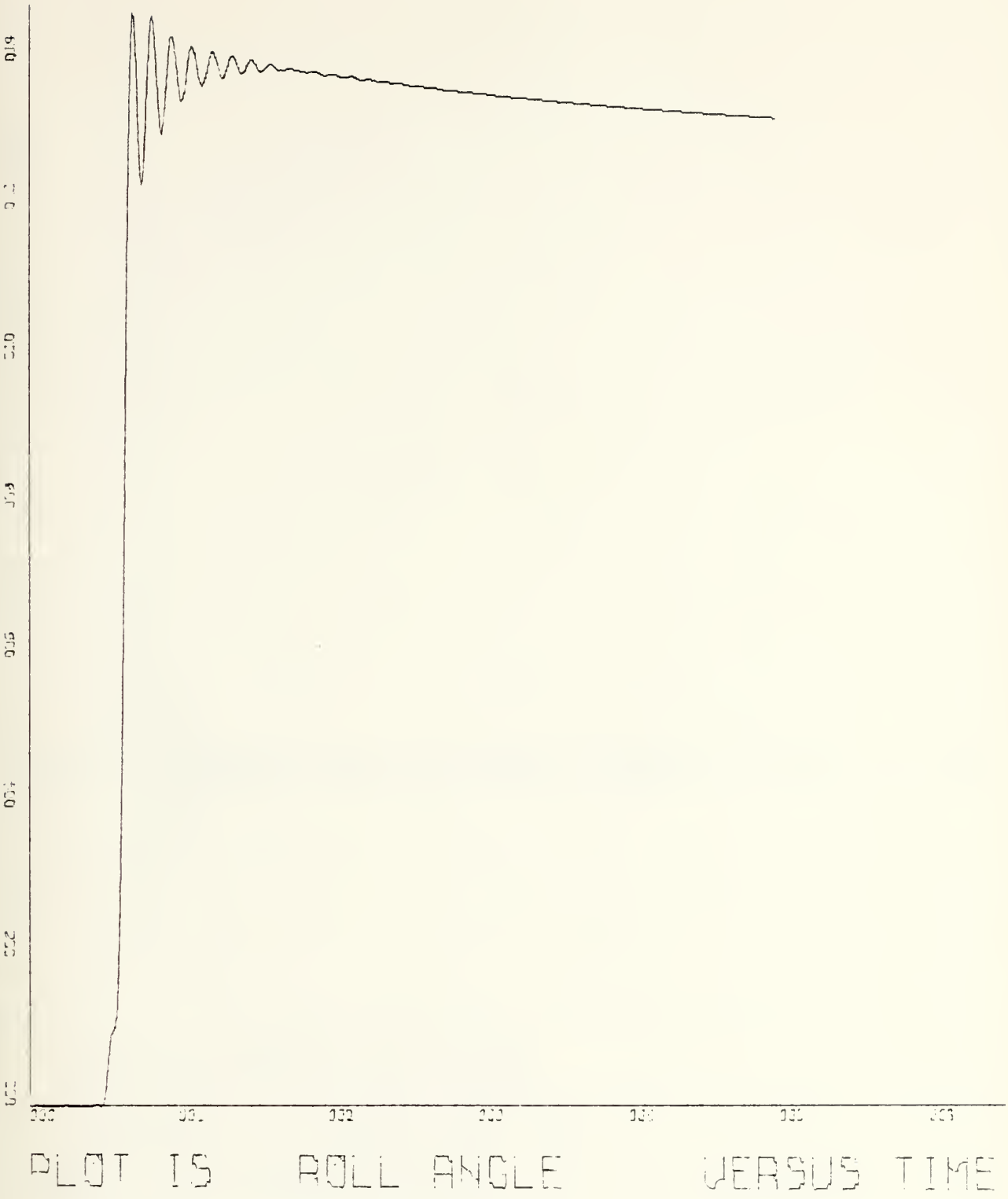
PLOT 49

for applied parameters see first page of this appendix



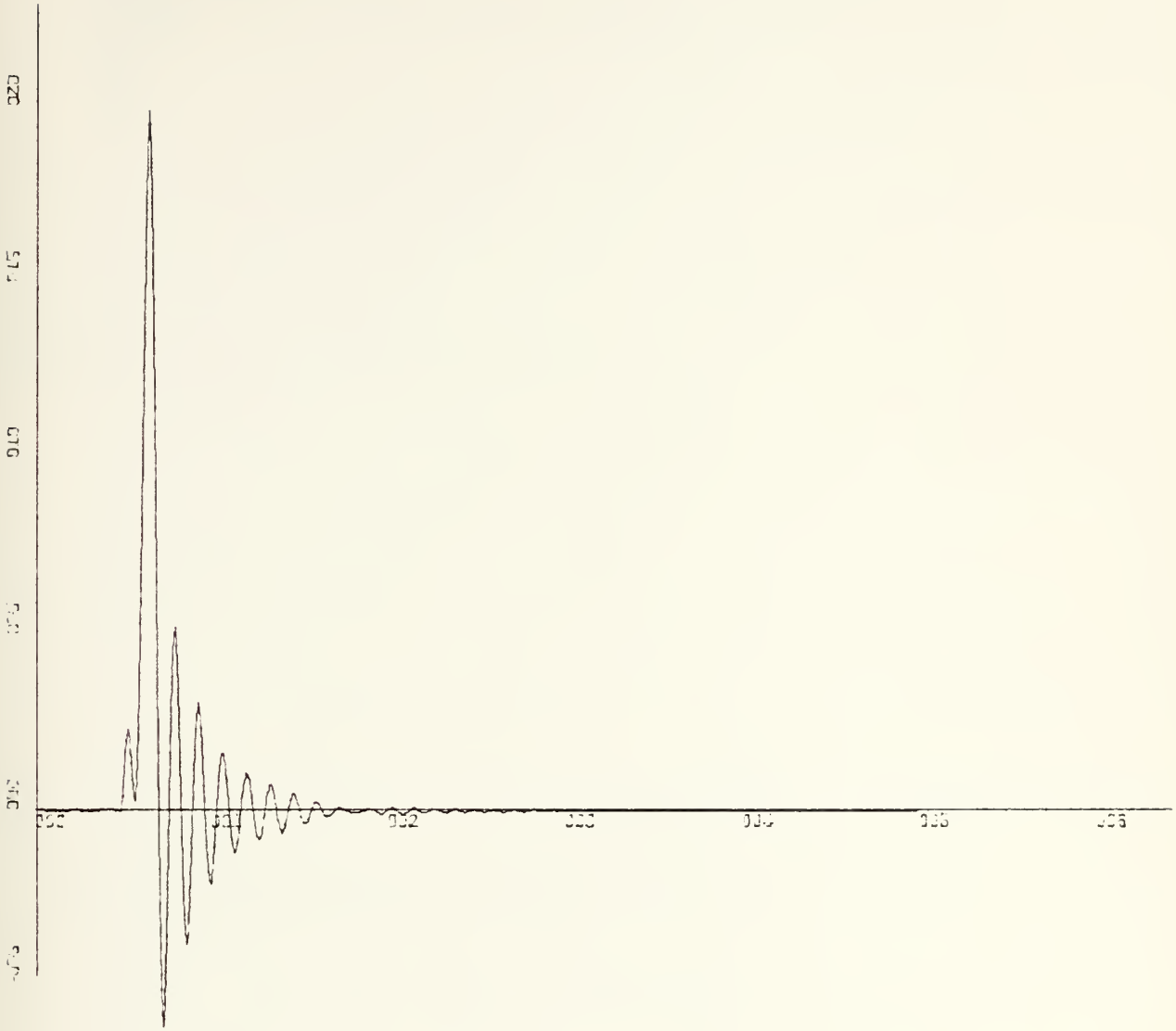
PLOT 50

for applied parameters see first page of this appendix



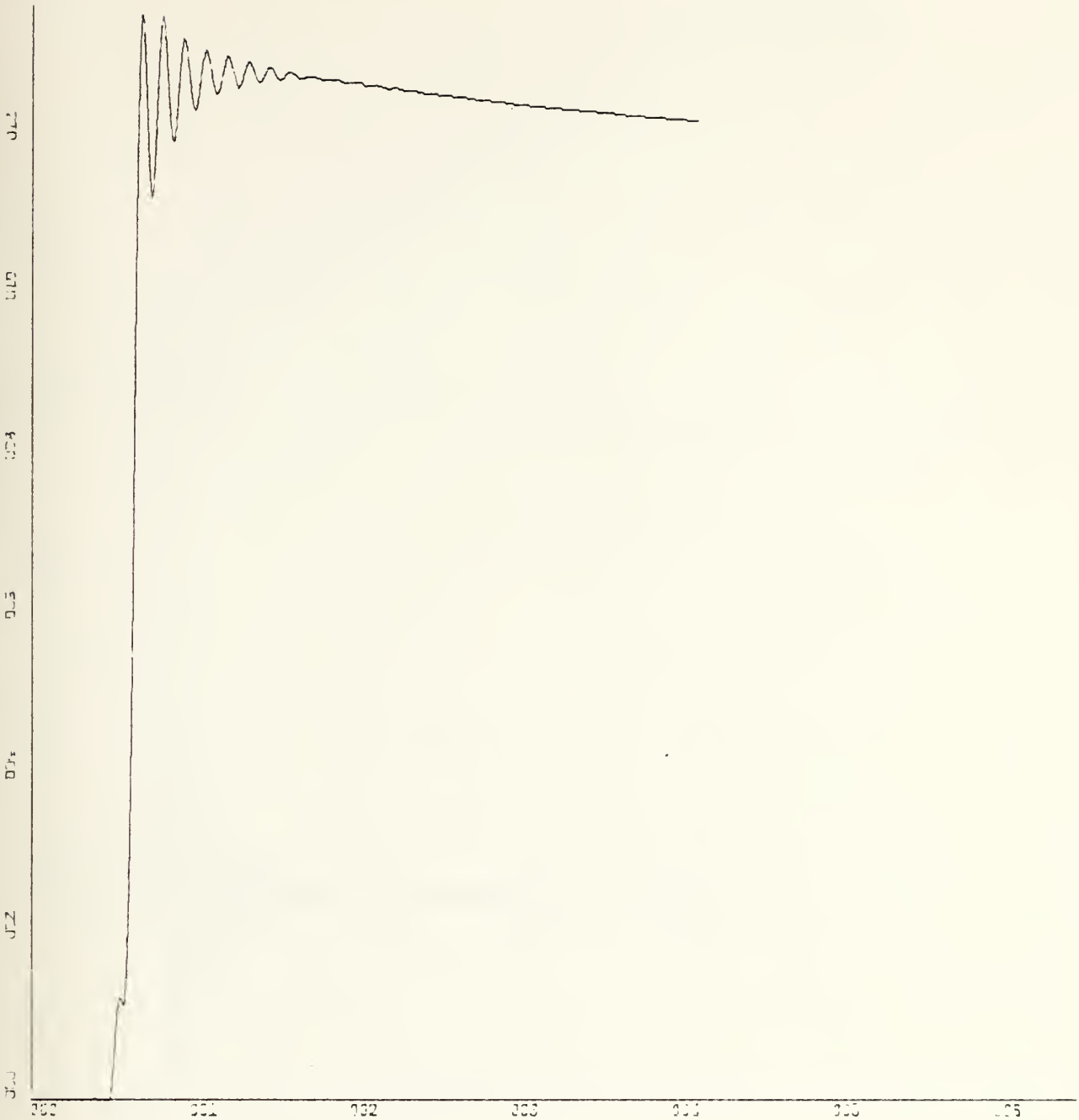
PLOT 51

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RUN002 , TURN 20 KN
PLOT IS ROLL RATE VERSUS TIME

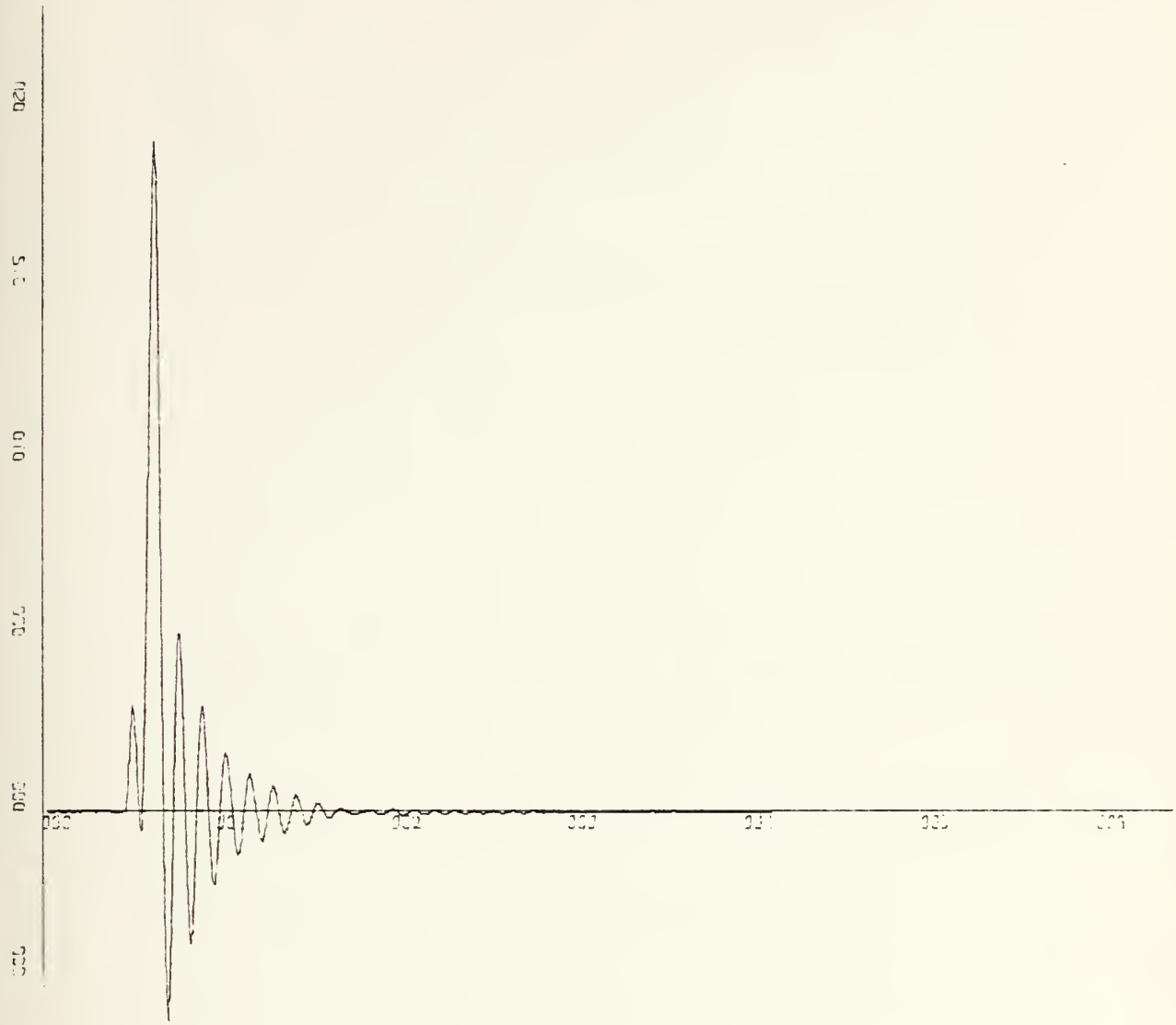
PLOT 52
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RUN003 , TURN 20 KN
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 53

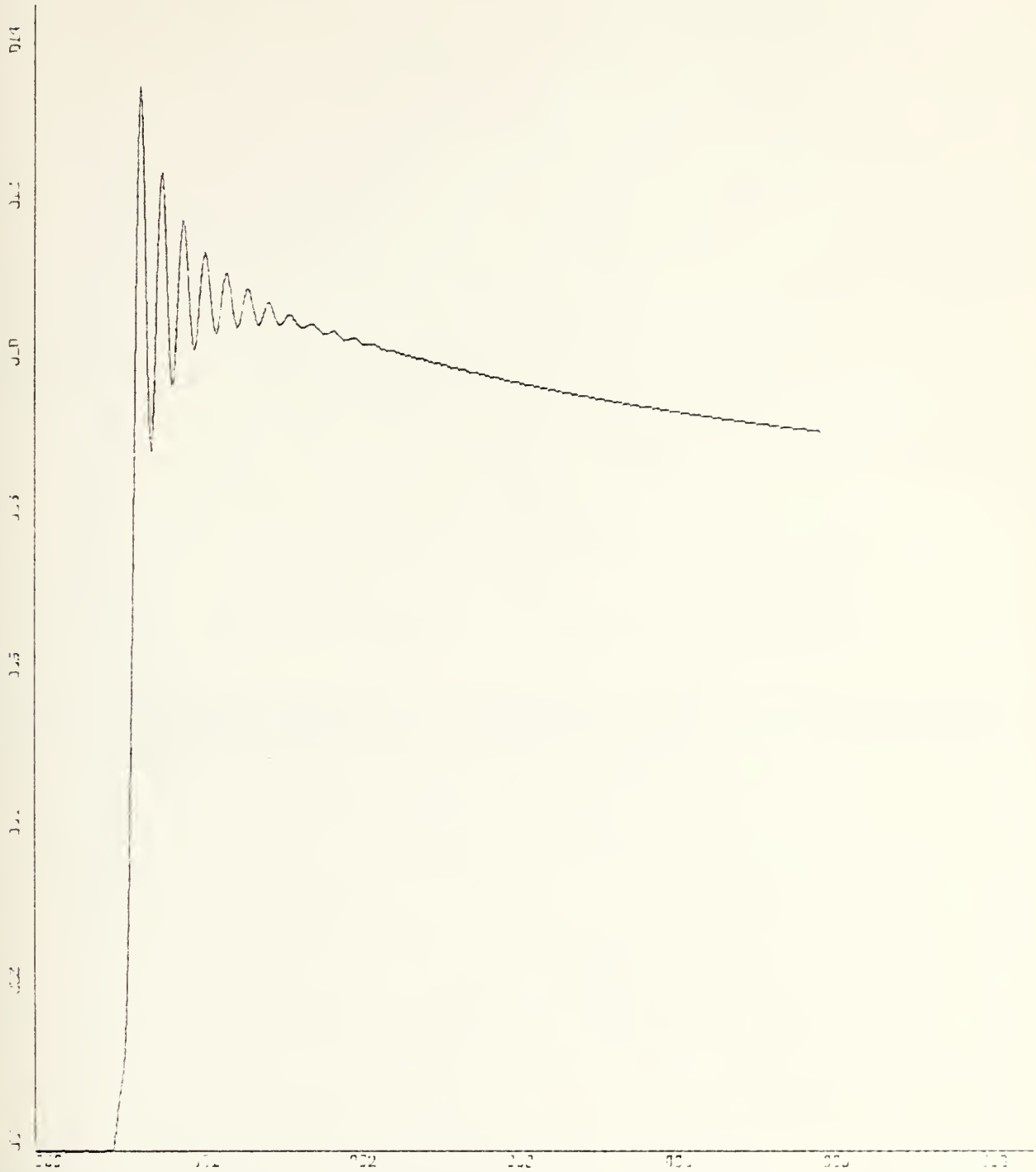
for applied parameters see first page of this appendix



X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 5.00E-01 UNITS INCH.
RUN003 . TURN 20 kN
PLOT IS ROLL RATE VERSUS TIME

PLOT 54

for applied parameters see first page of this appendix

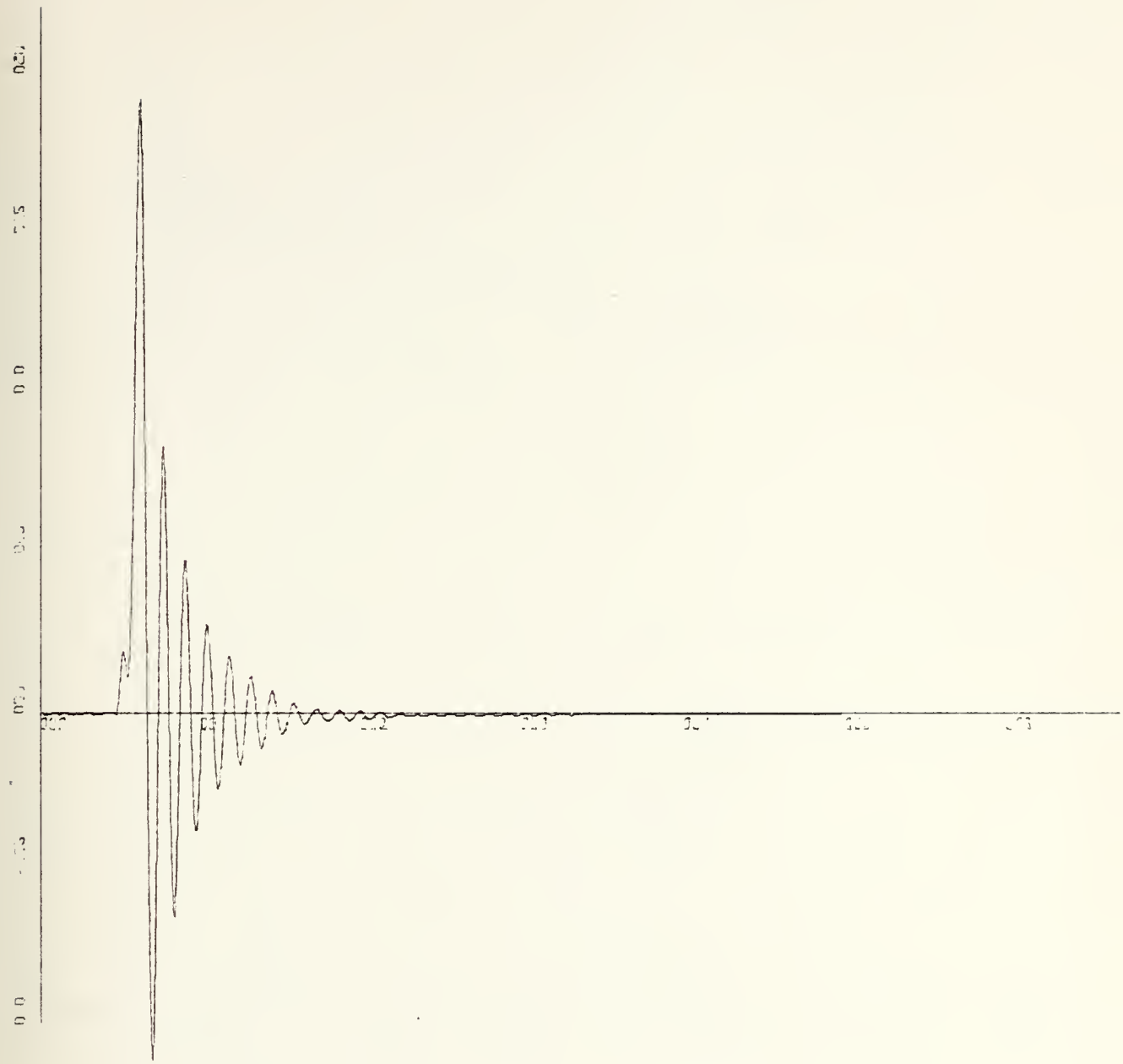


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE: 1.00E+01 UNITS INCH.
Y-SCALE: 2.00E-01 UNITS INCH.

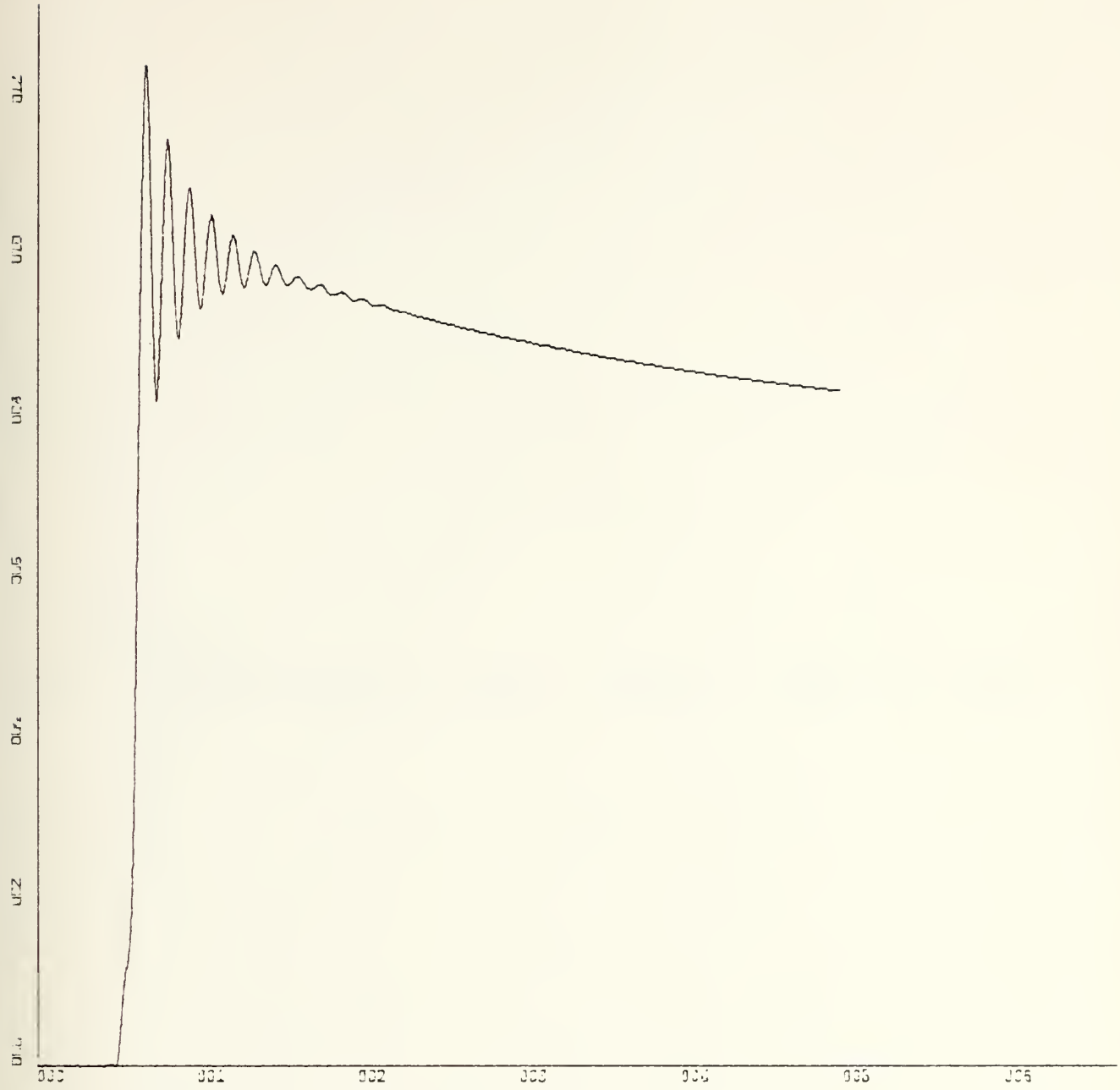
PLOT 55

for applied parameters see first page of this appendix



PLOT 56

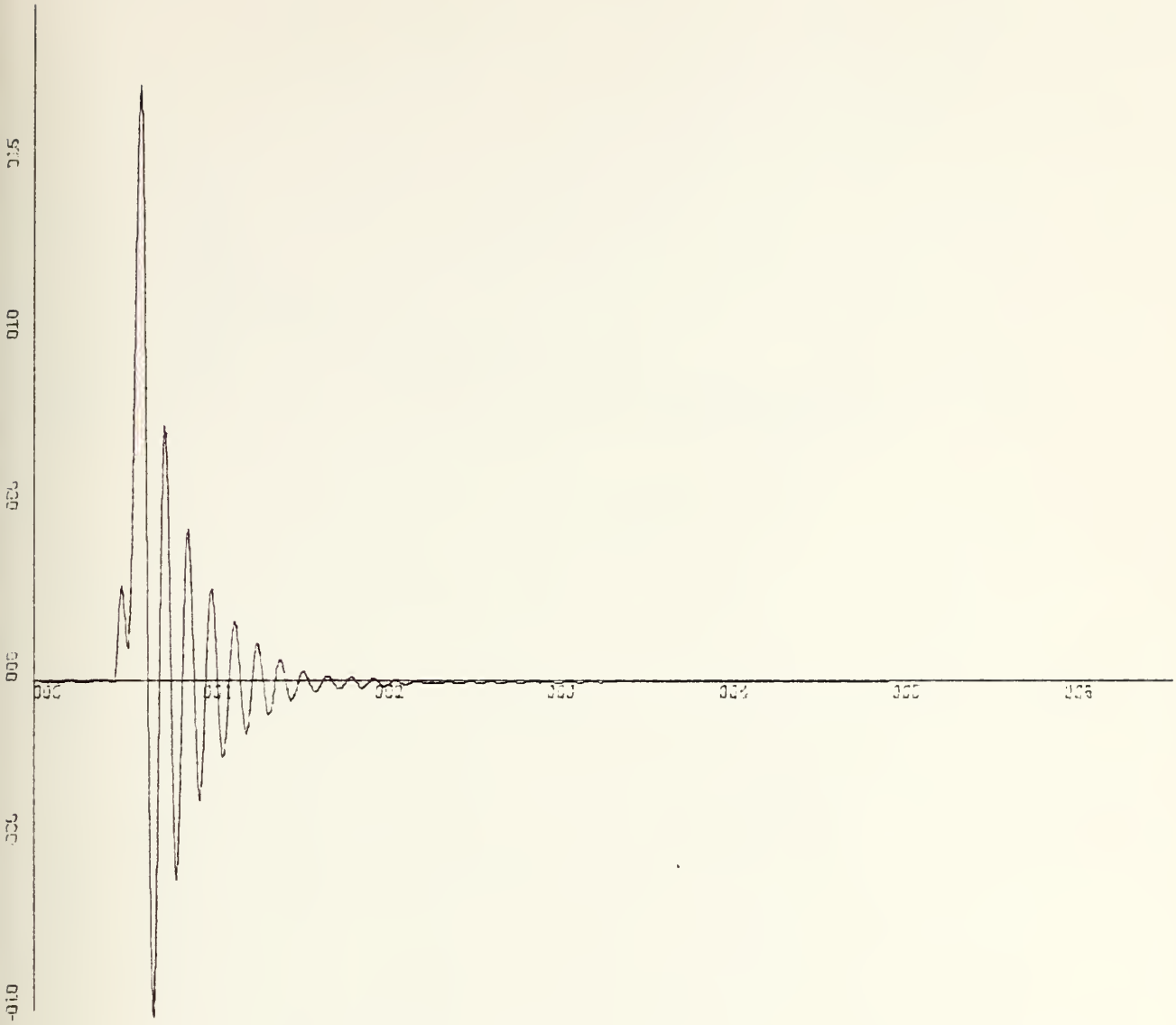
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RGROF4 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL ANGLE VERSUS TIME

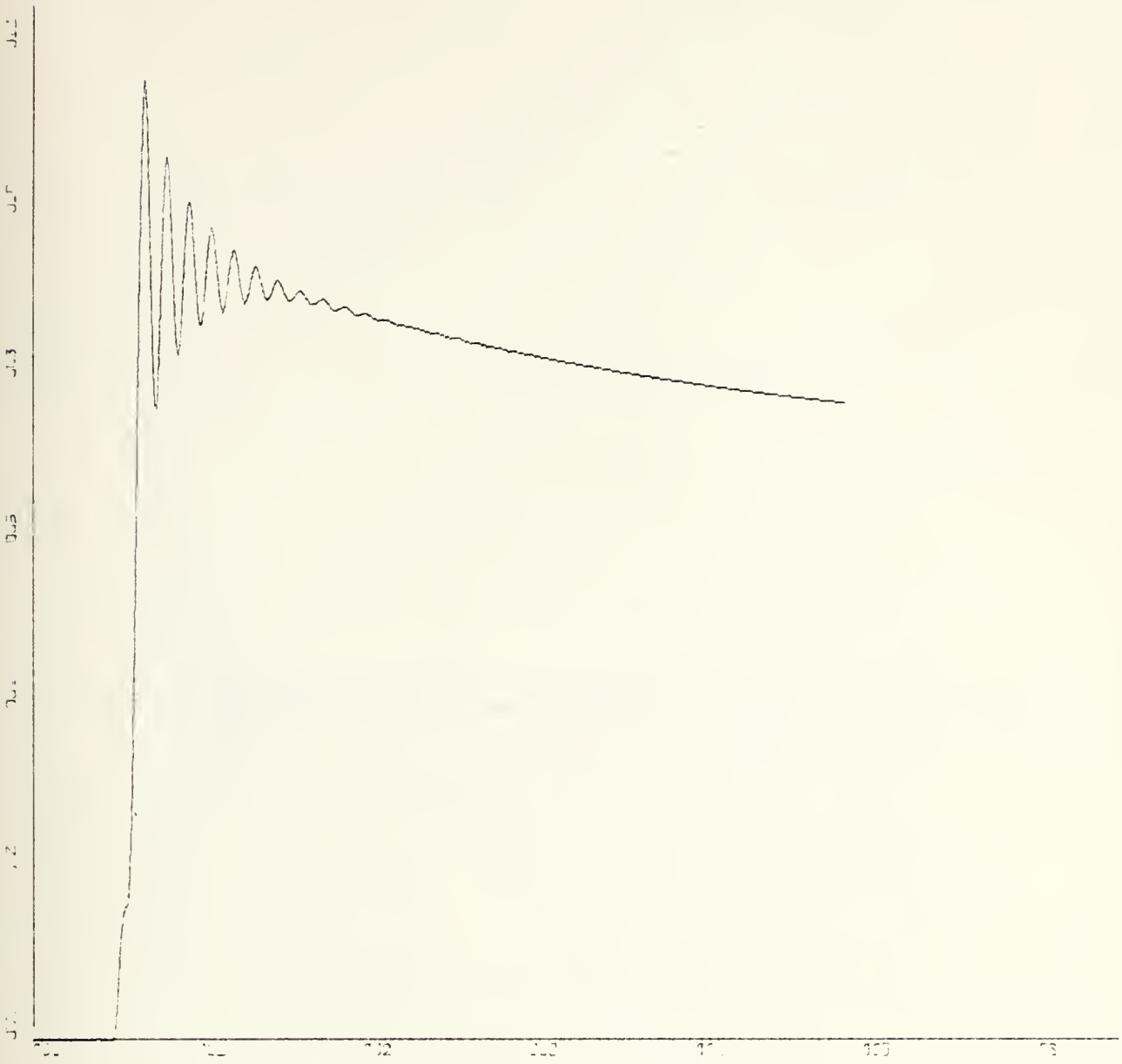
PLOT 57

for applied parameters see first page of this appendix



PLOT 58

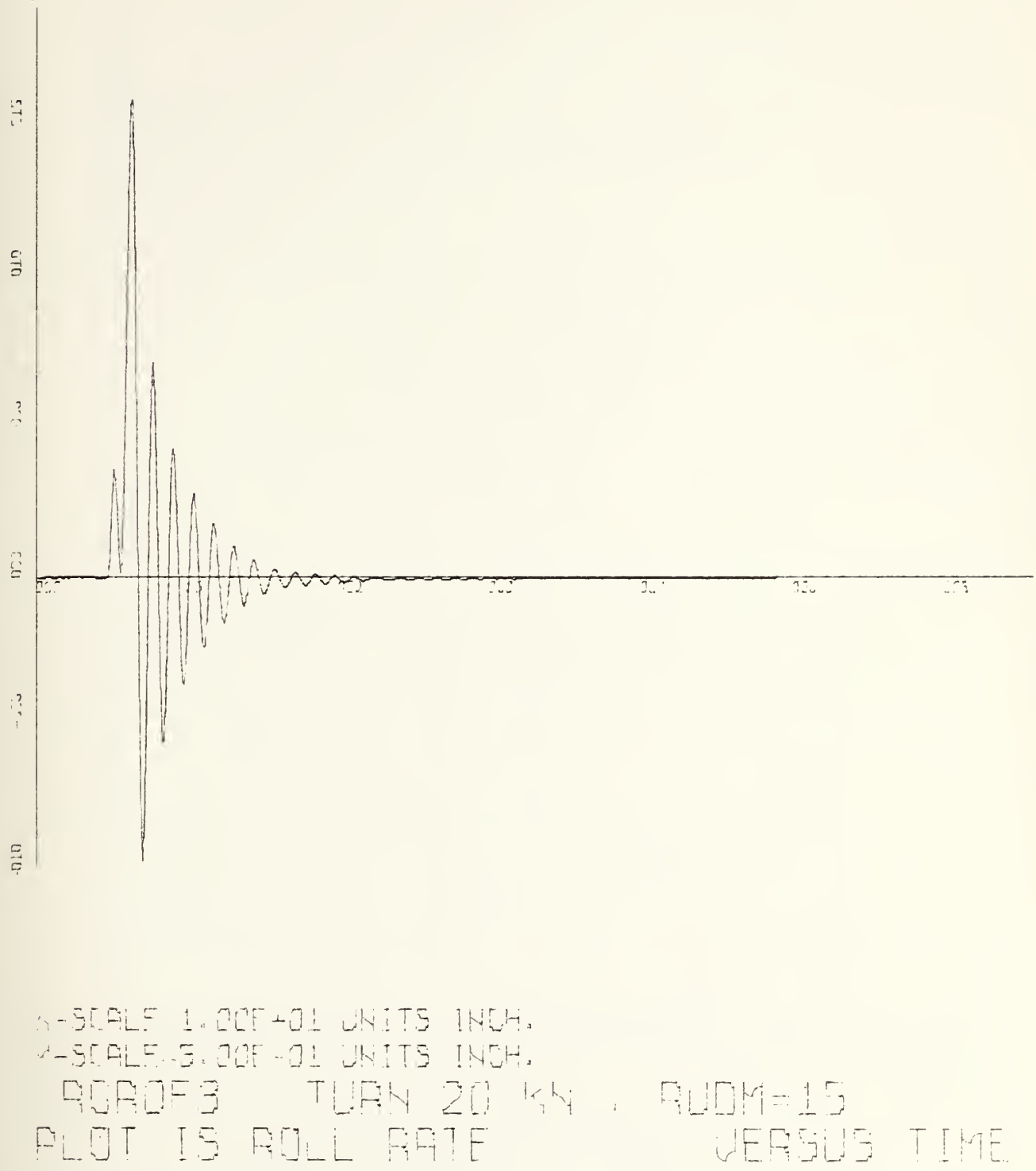
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.
BCROF3 , TURN 20 KN , RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

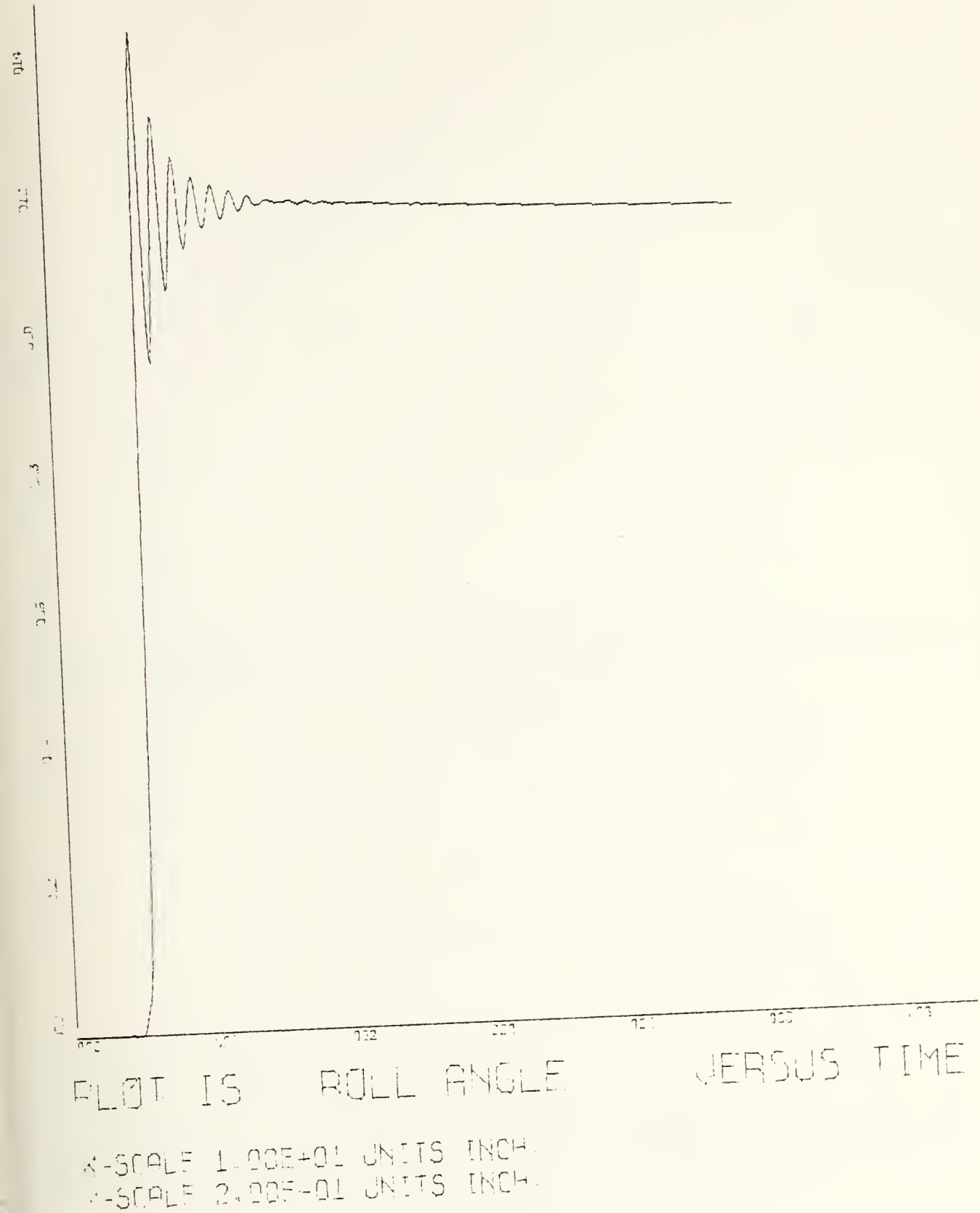
PLOT 59

for applied parameters see first page of this appendix



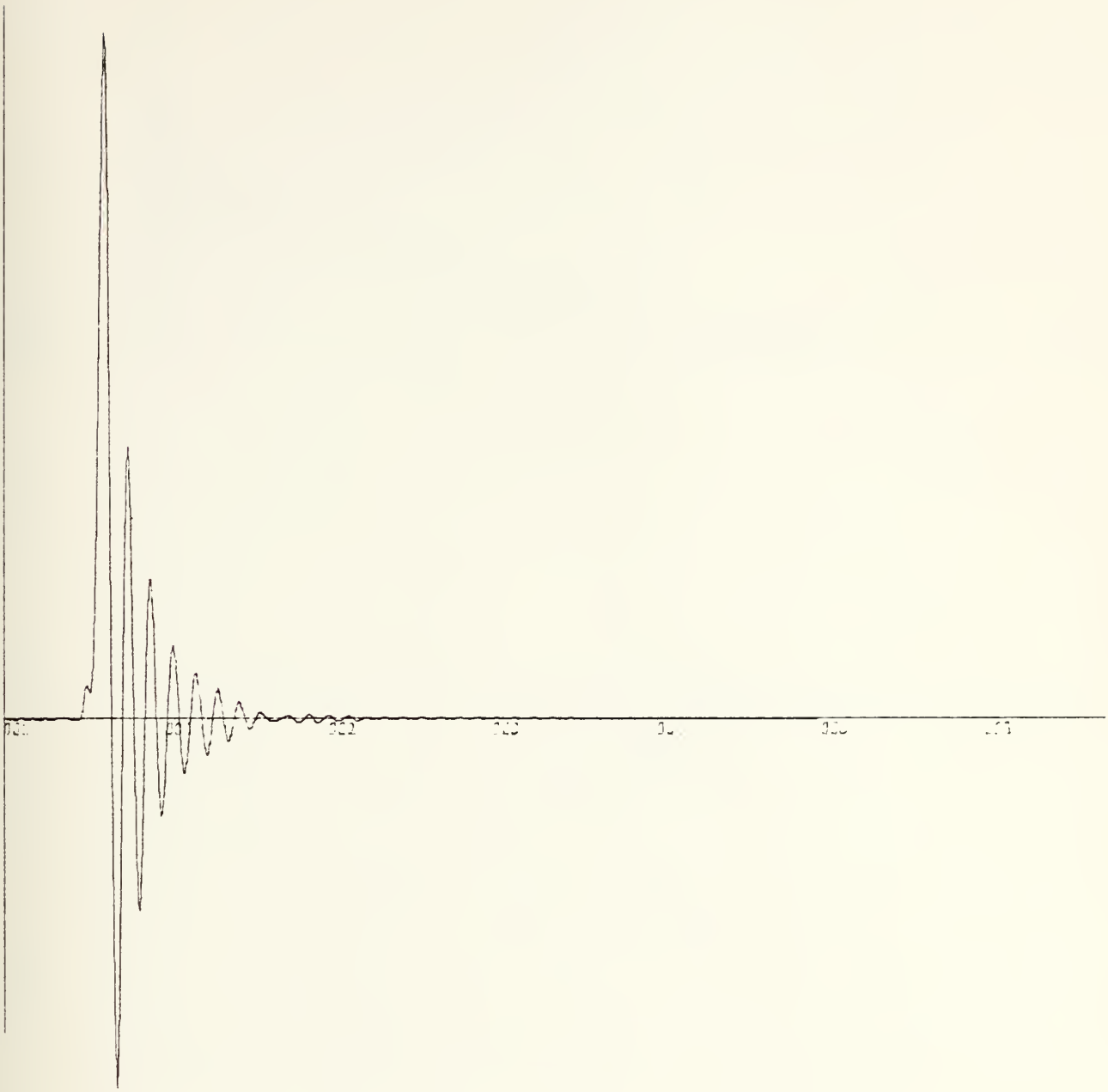
PLOT 60

for applied parameters see first page of this appendix



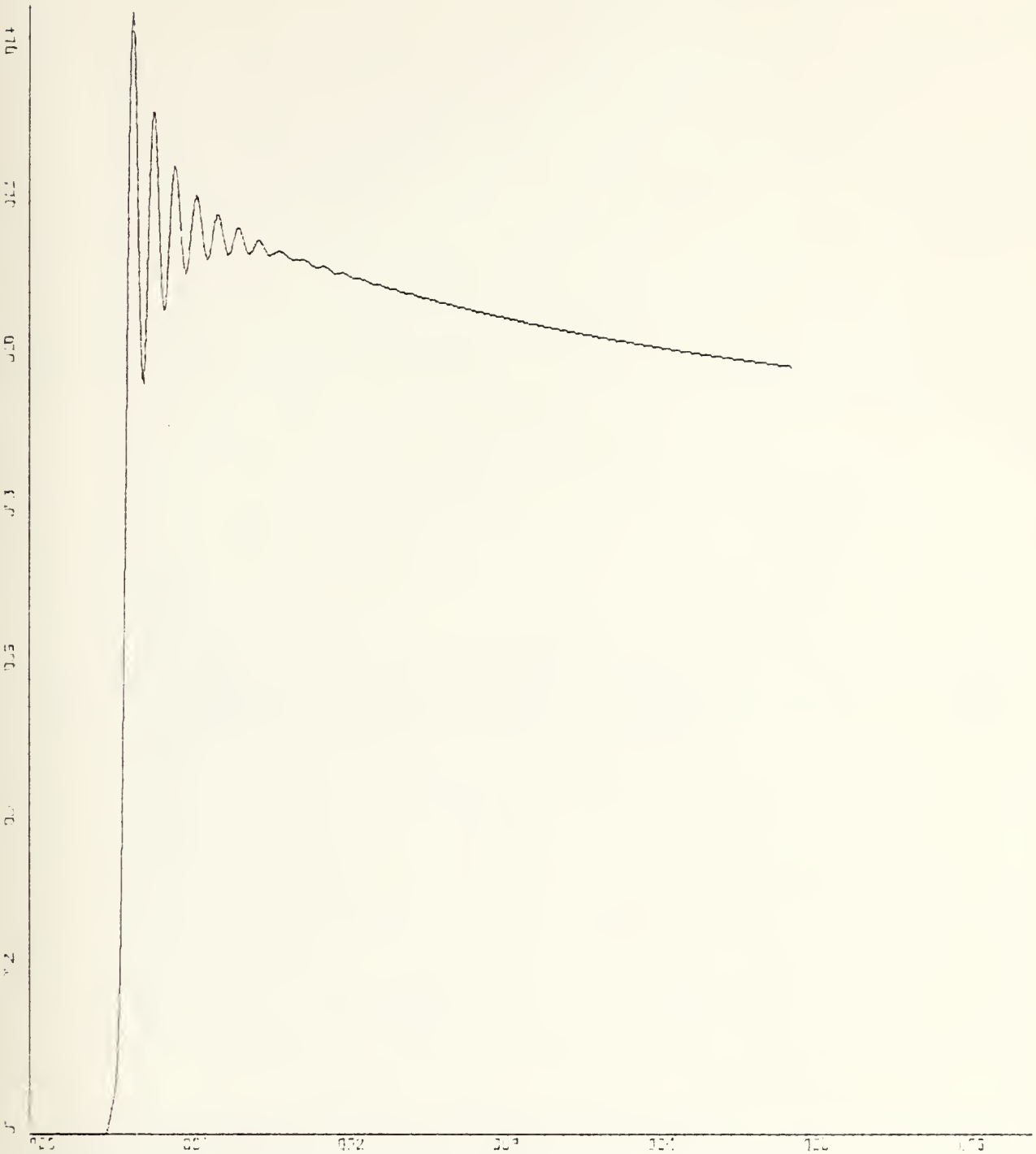
PLOT 61

for applied parameters see first page of this appendix



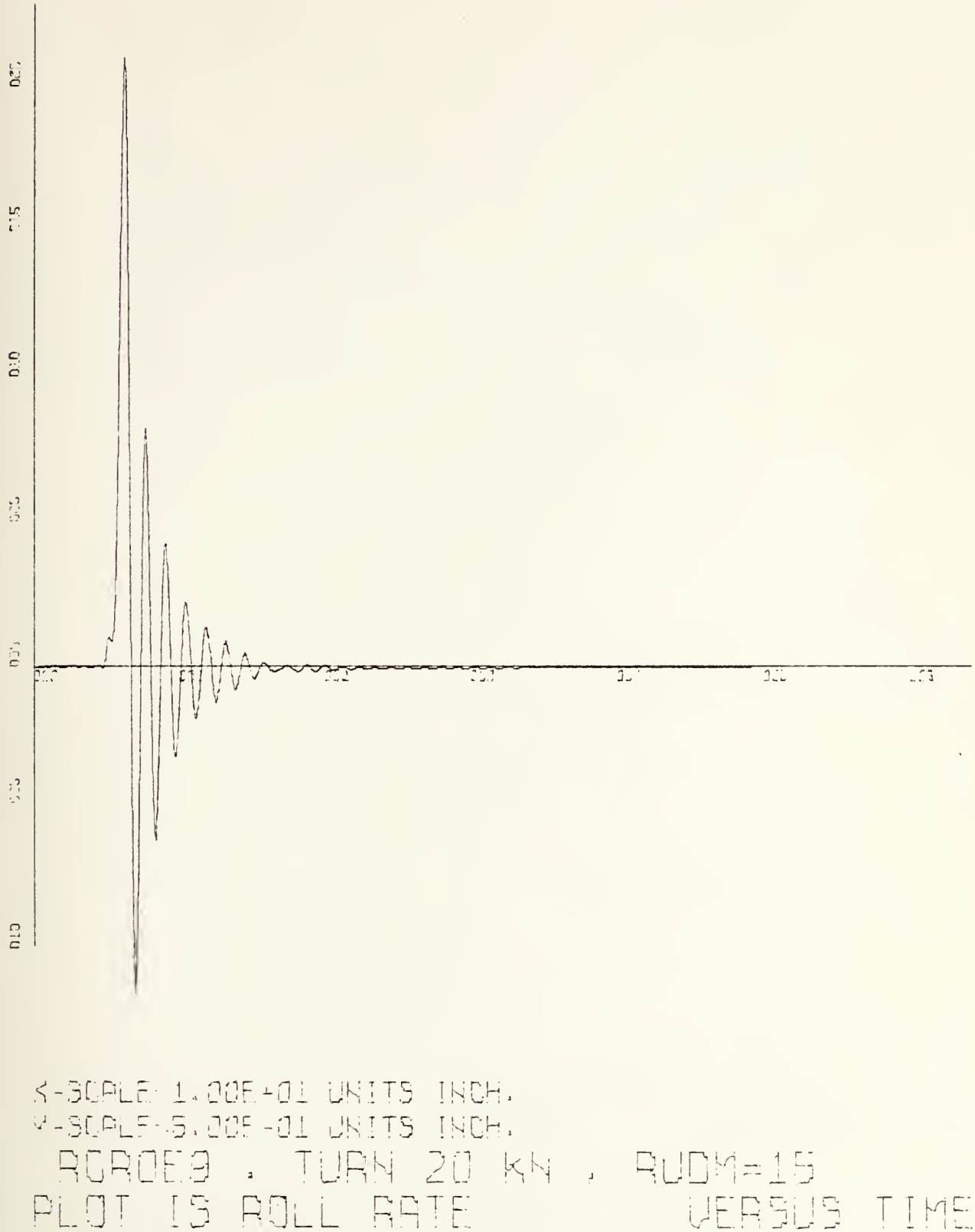
PLOT 62

for applied parameters see first page of this appendix



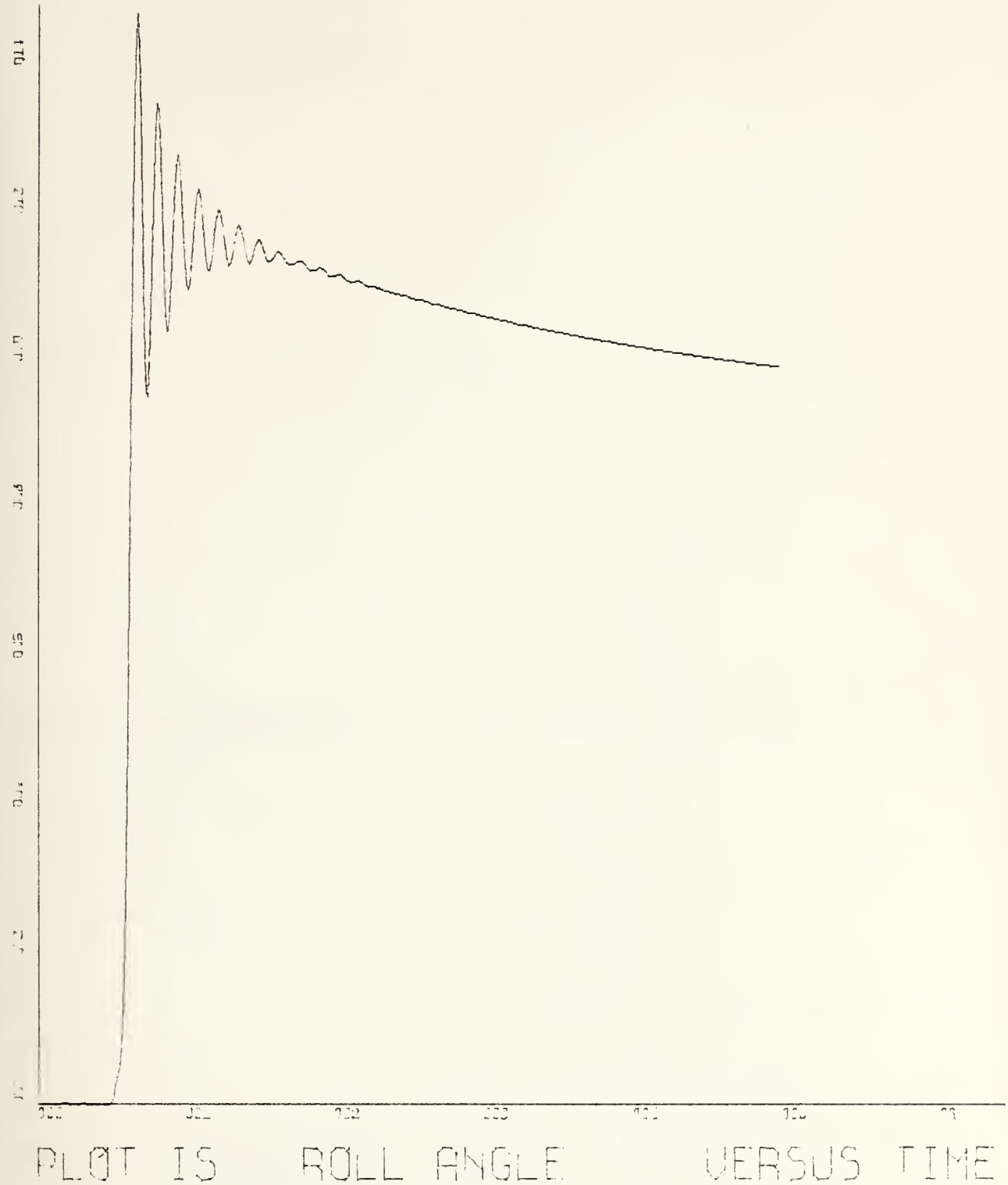
PLOT 63

for applied parameters see first page of this appendix



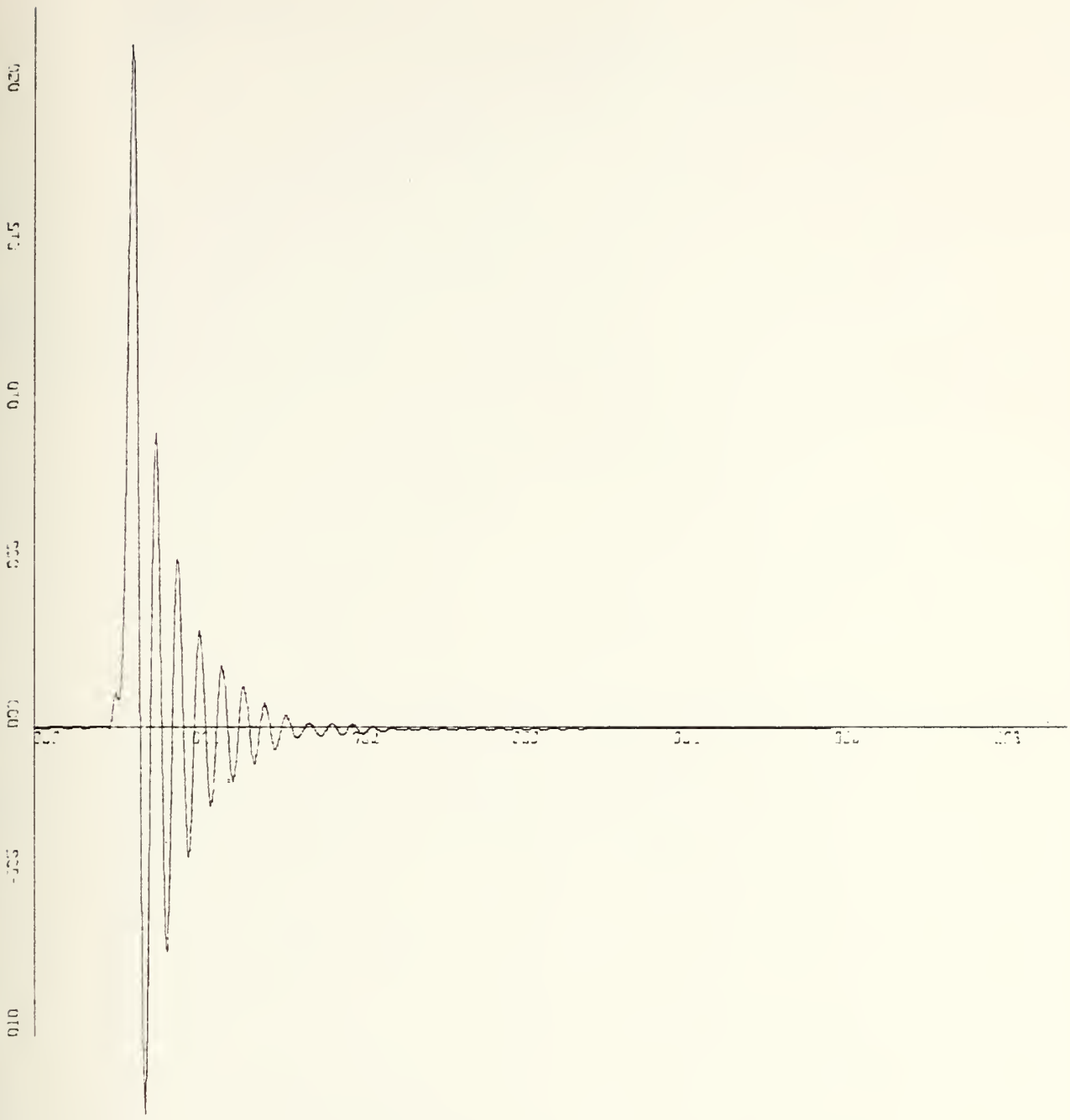
PLOT 64

for applied parameters see first page of this appendix



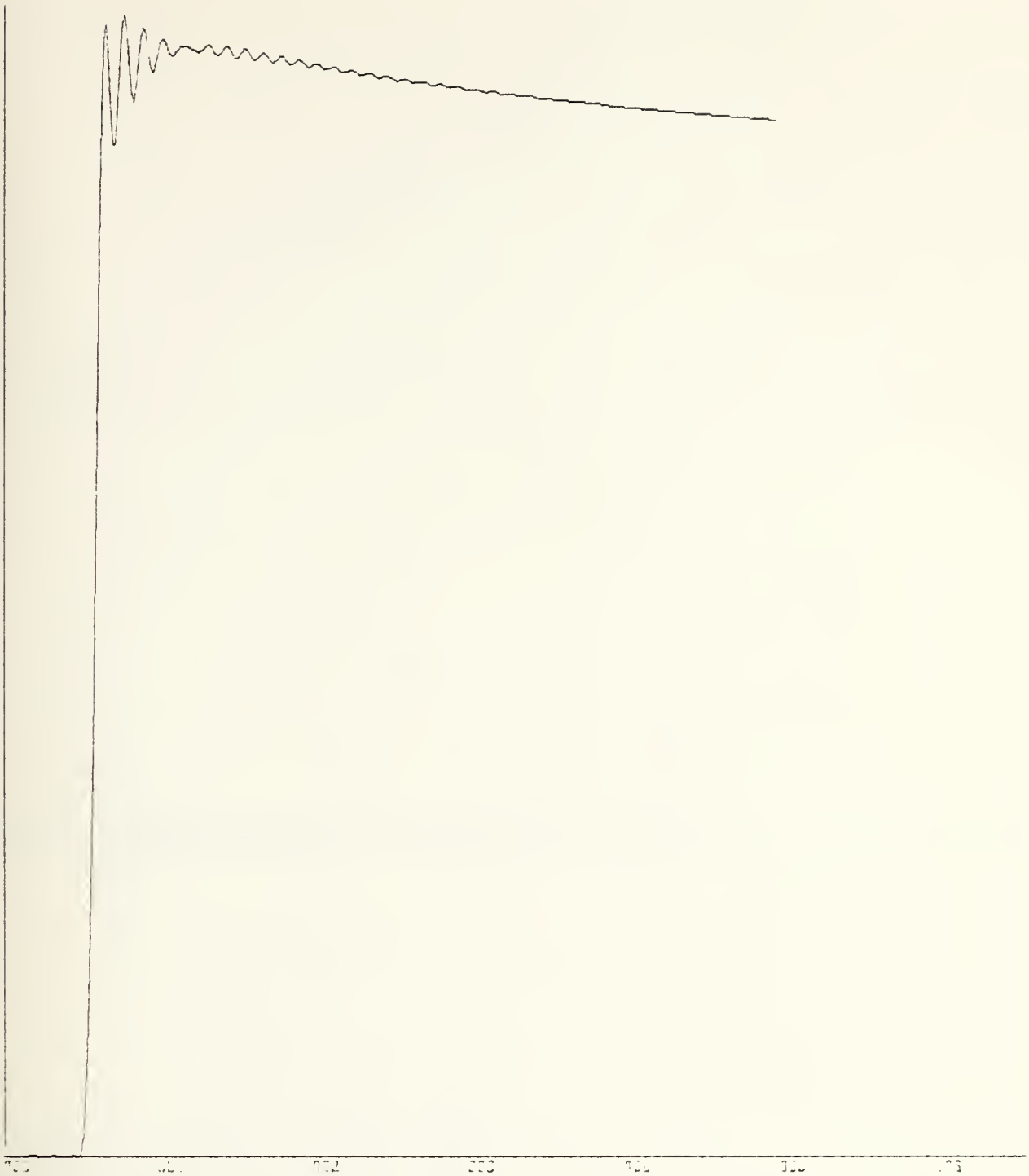
PLOT 65

for applied parameters see first page of this appendix



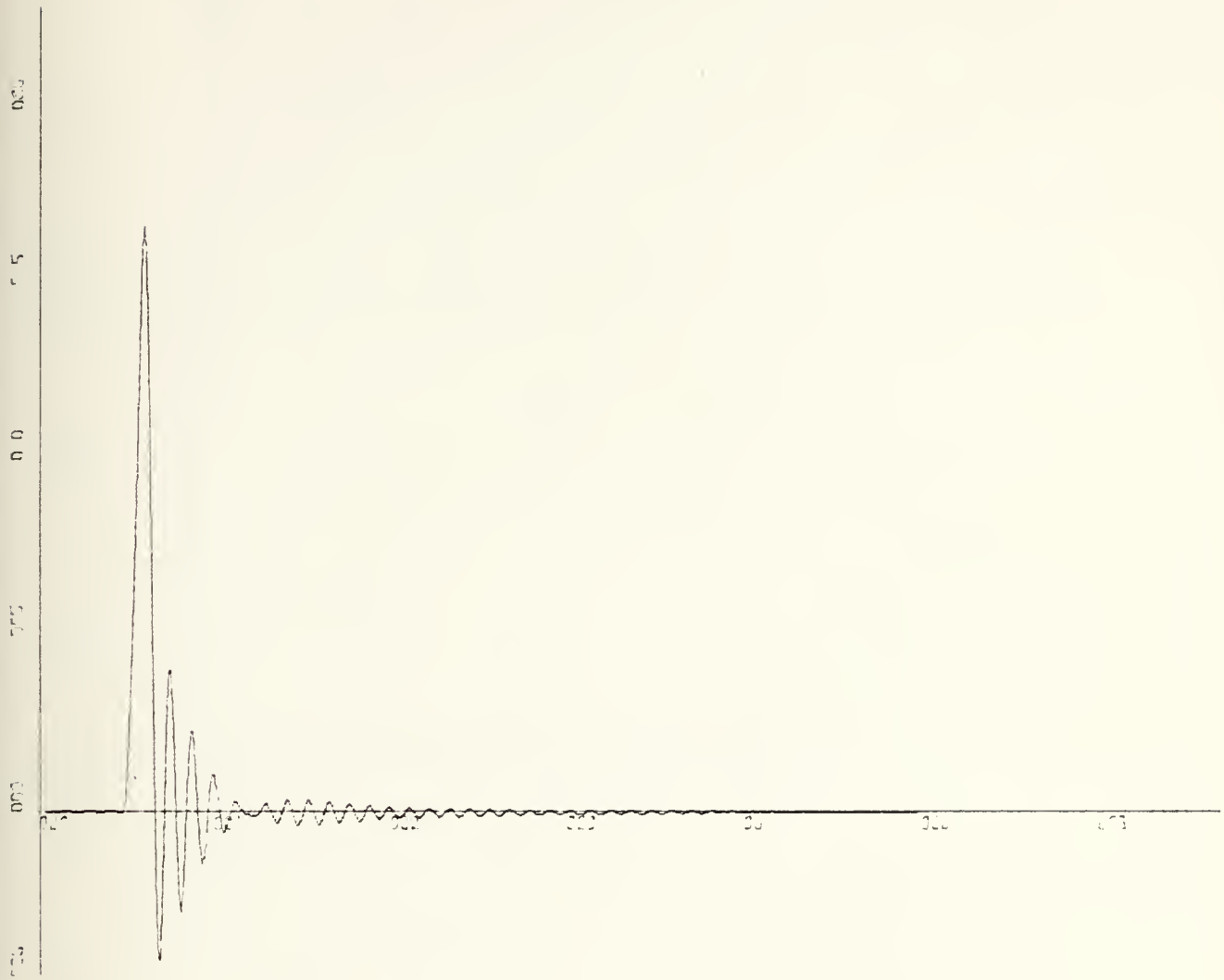
PLOT 66

for applied parameters see first page of this appendix



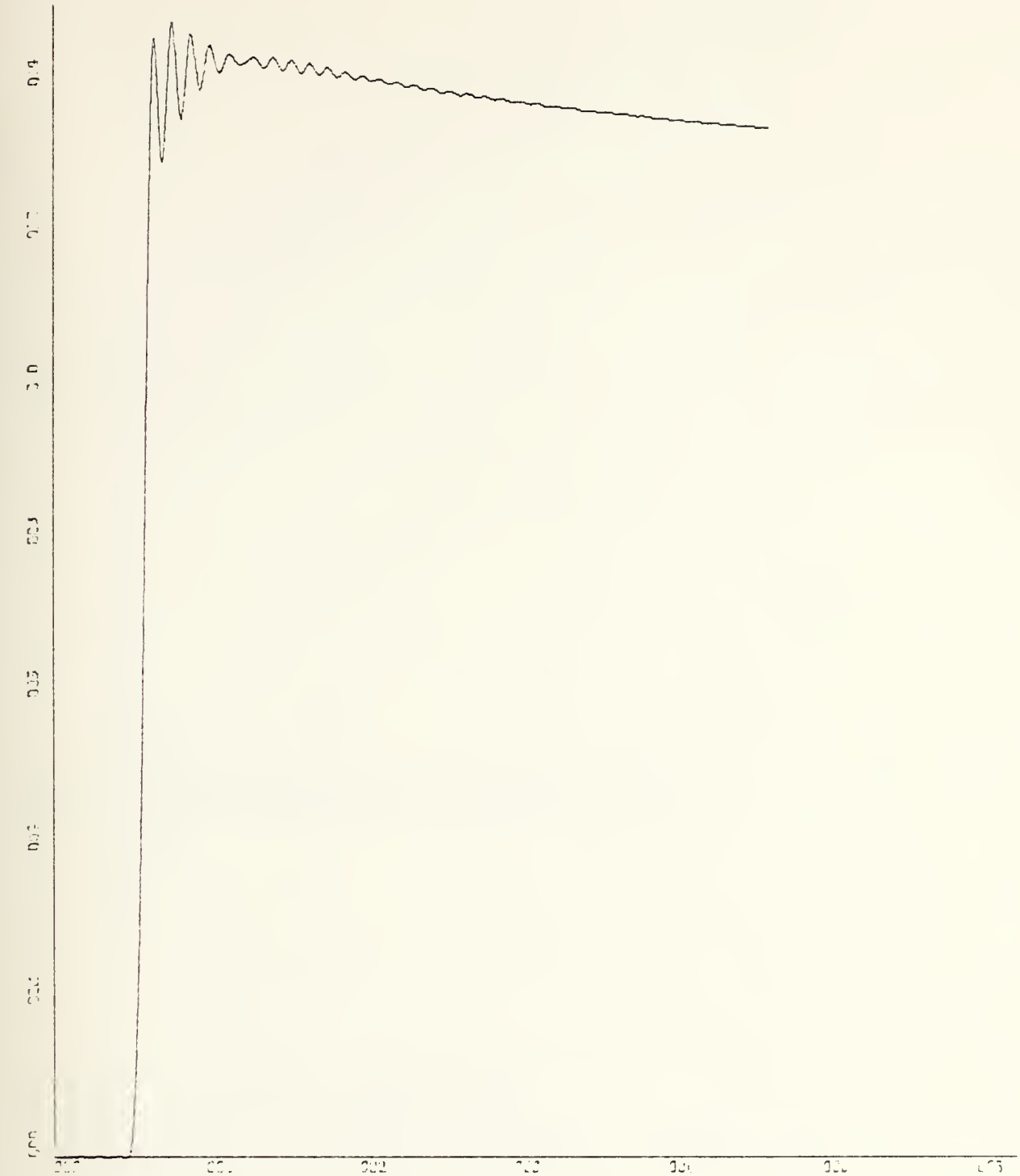
PLOT 67

for applied parameters see first page of this appendix



PLOT 68

for applied parameters see first page of this appendix

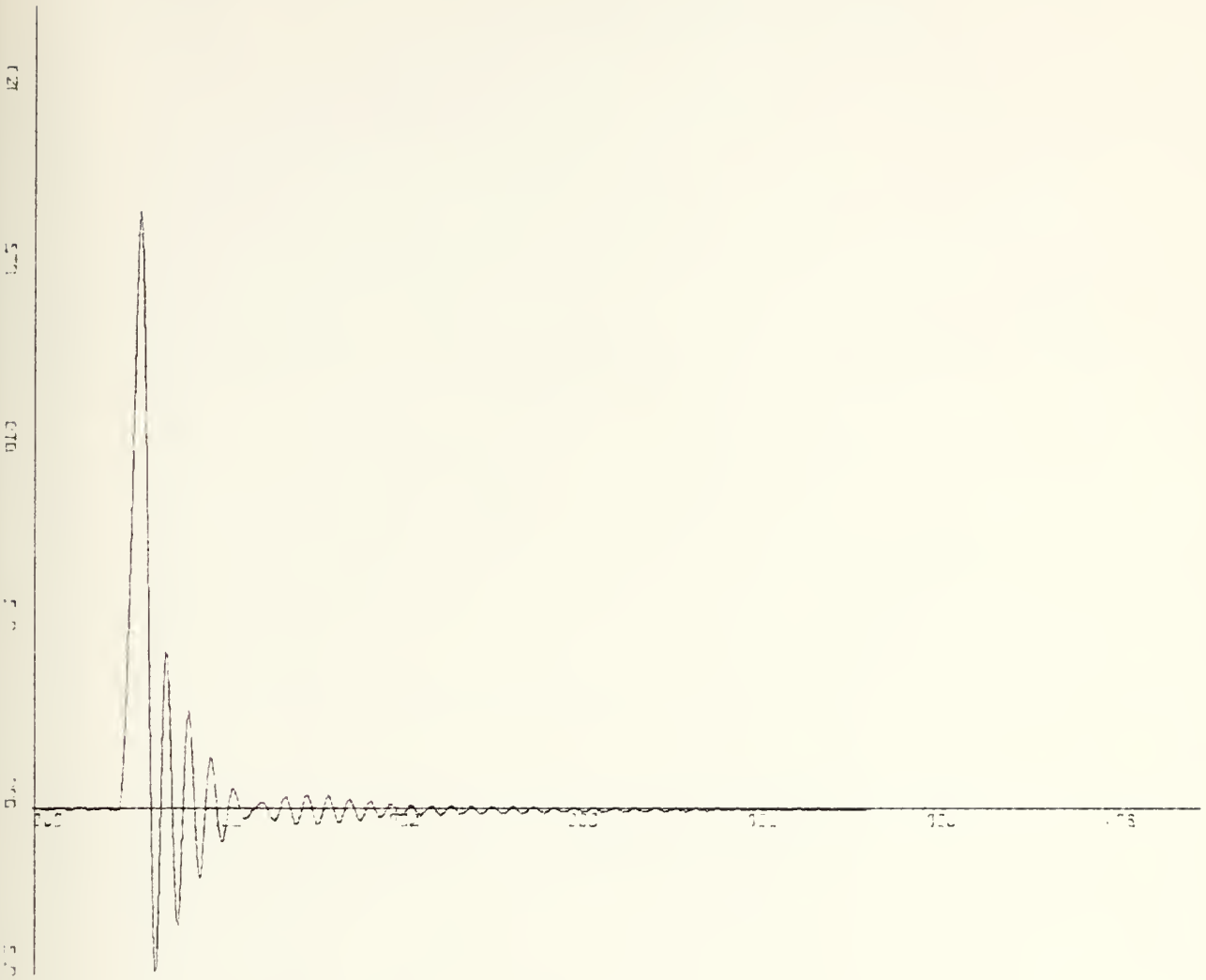


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.

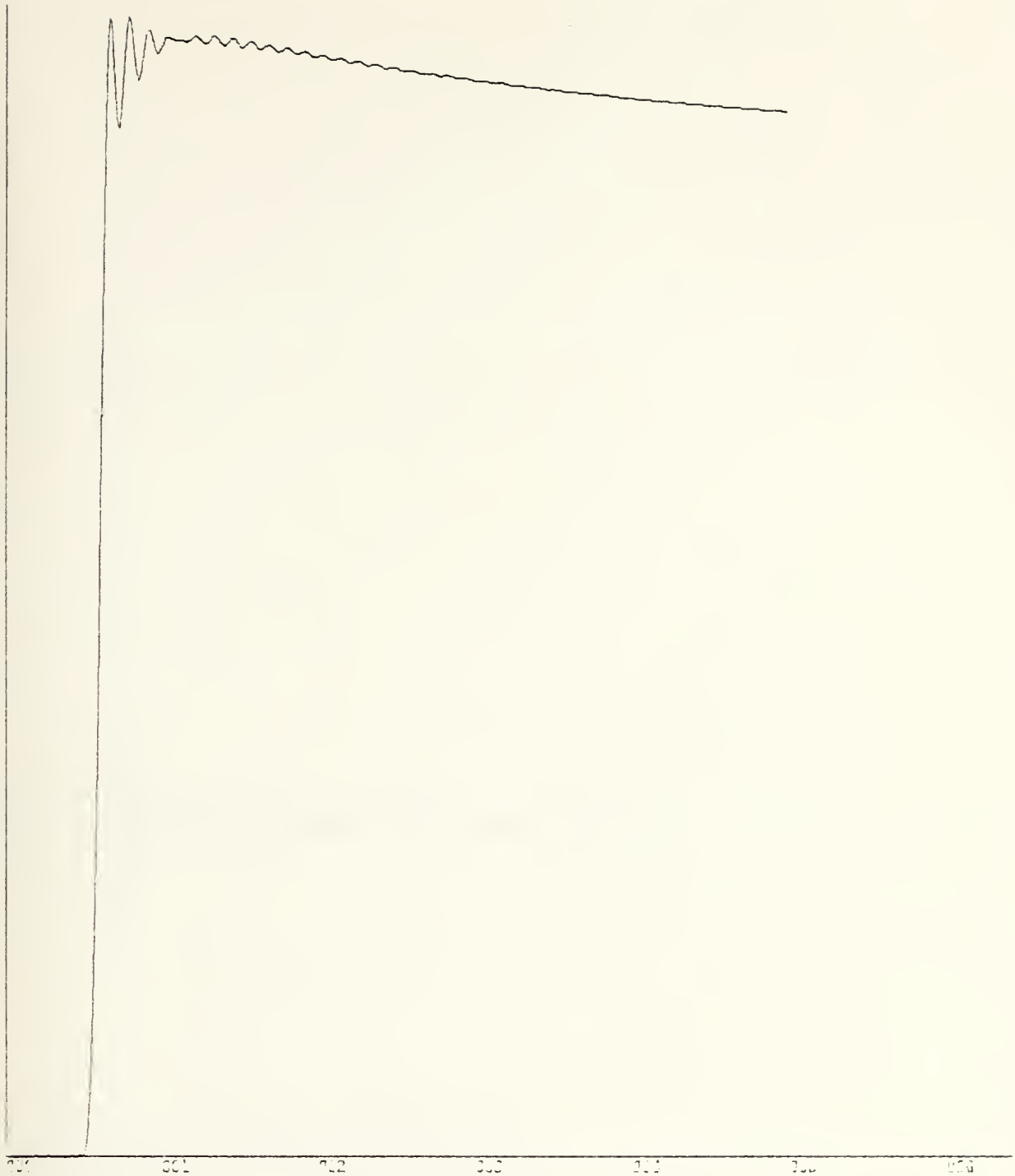
PLOT 69

for applied parameters see first page of this appendix



PLOT 70

for applied parameters see first page of this appendix

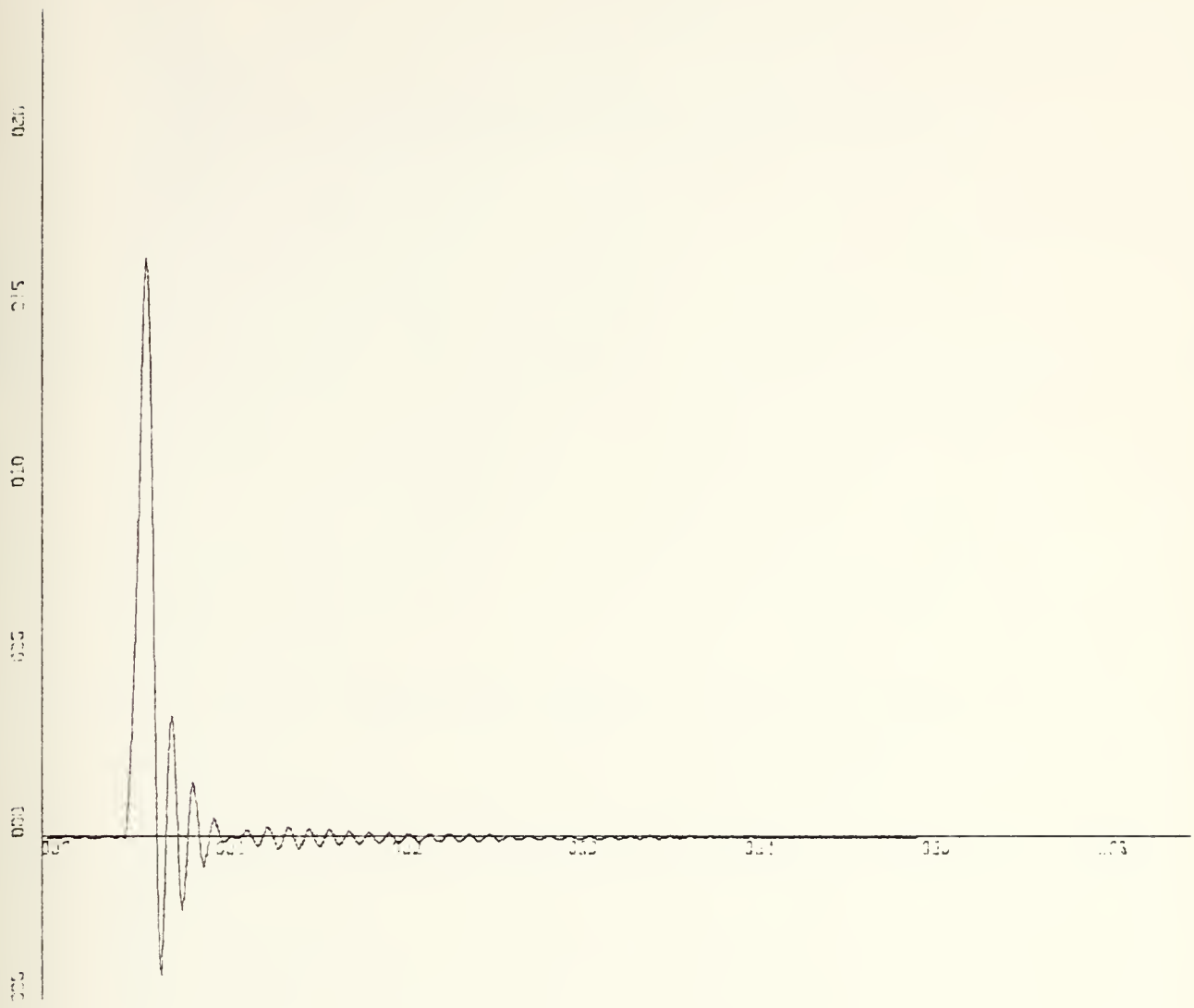


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 2.00E-01 UNITS INCH.

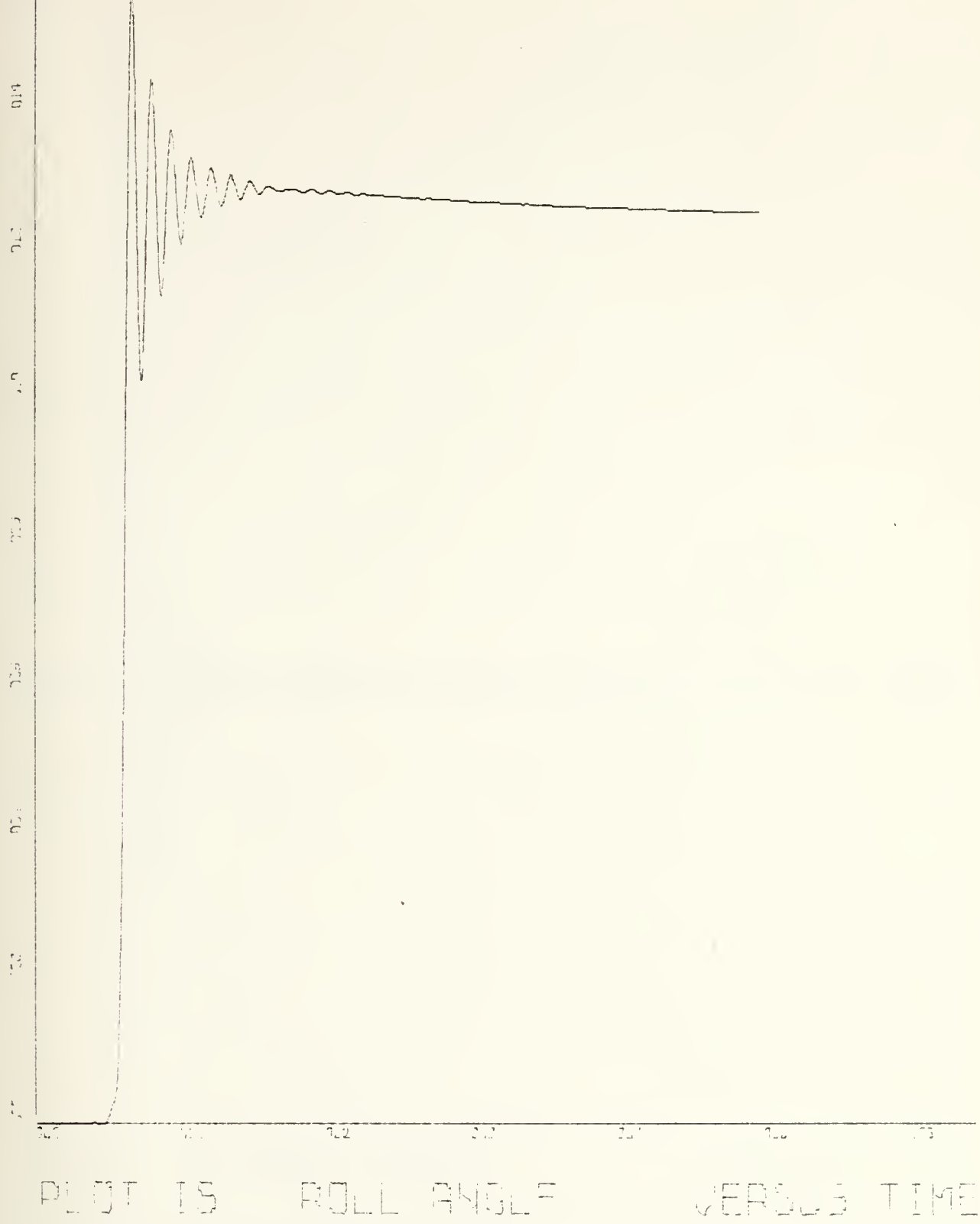
PLOT 71

for applied parameters see first page of this appendix



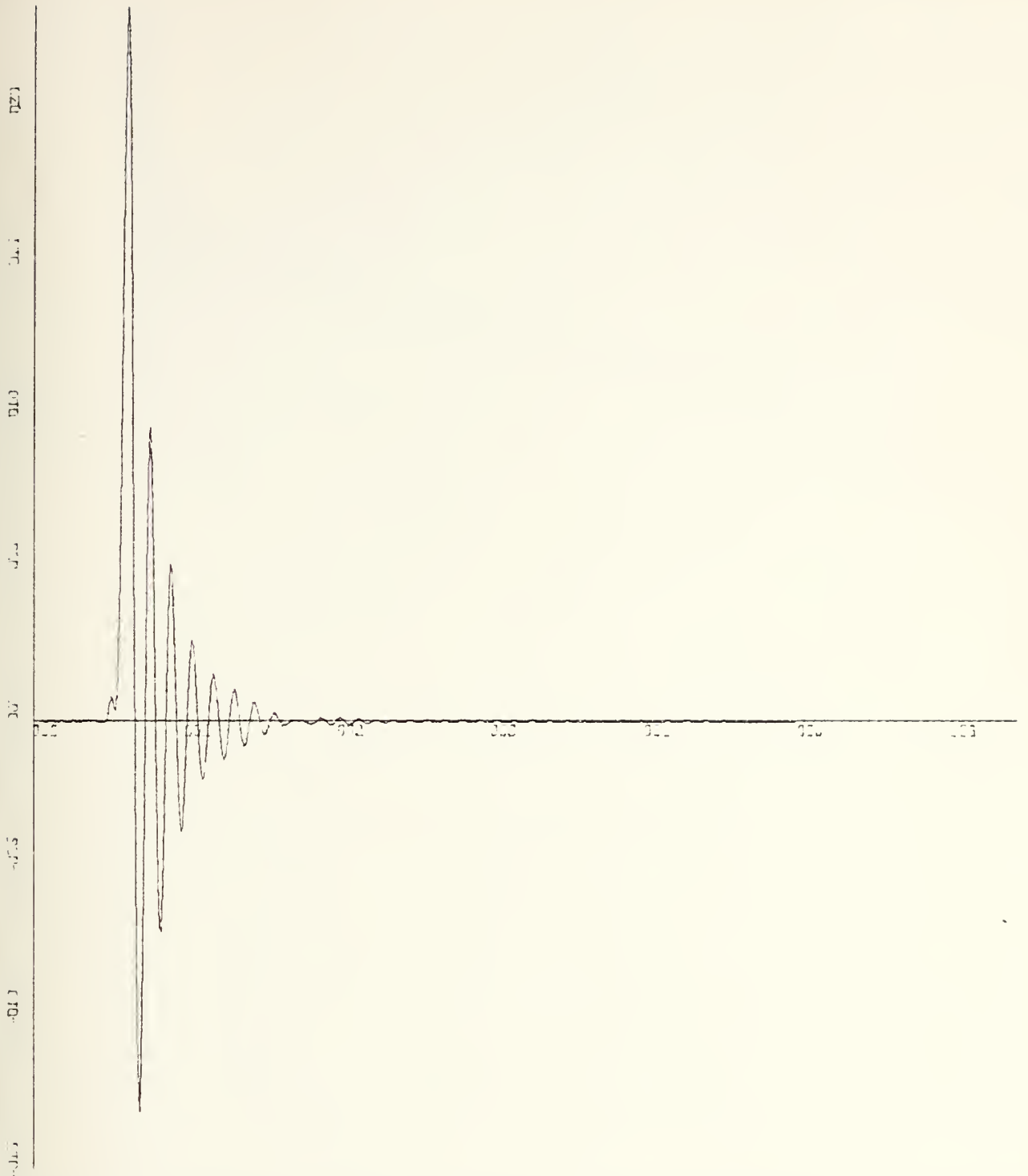
PLOT 72

for applied parameters see first page of this appendix



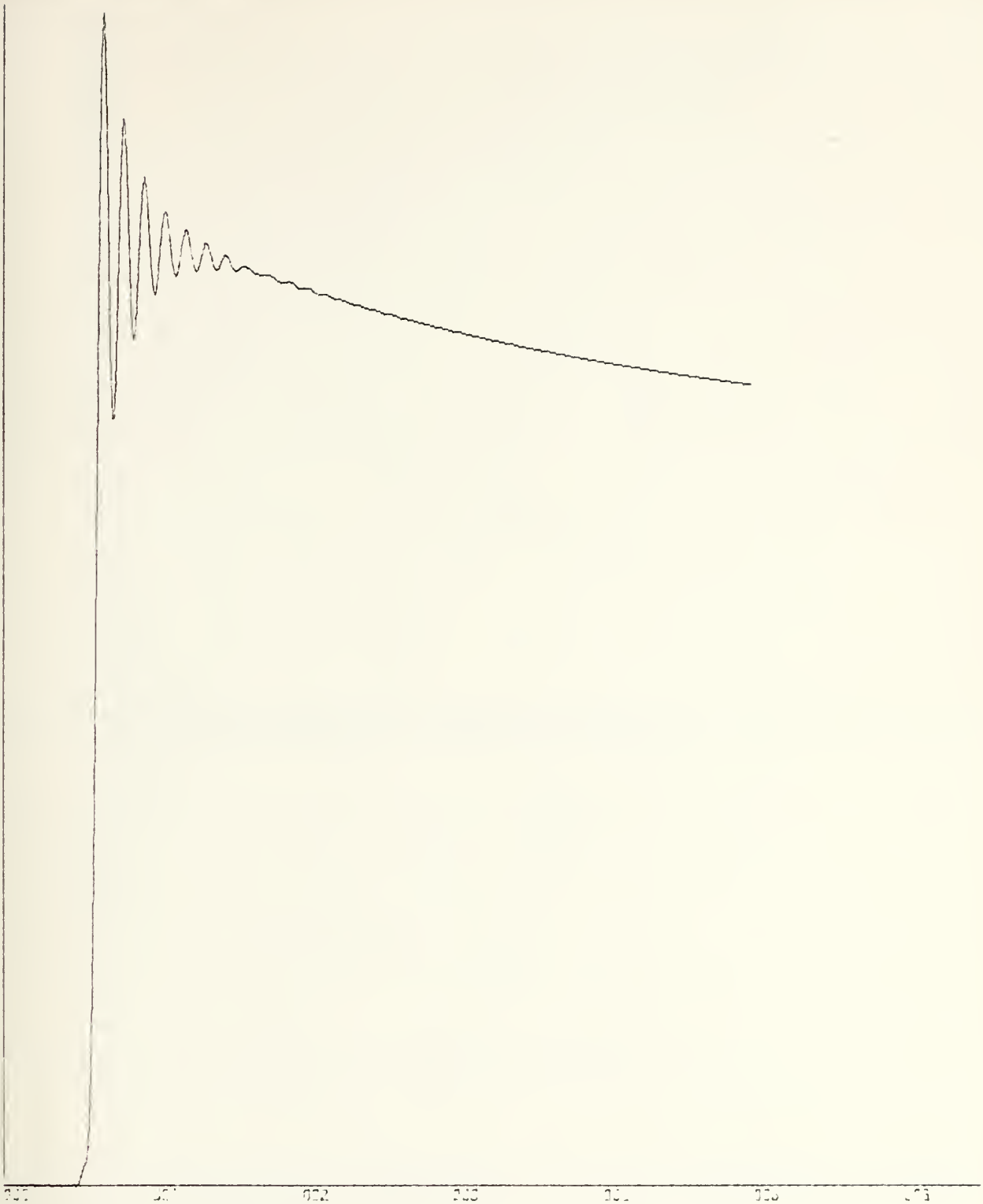
PLOT 73

for applied parameters see first page of this appendix



PLOT 74

for applied parameters see first page of this appendix

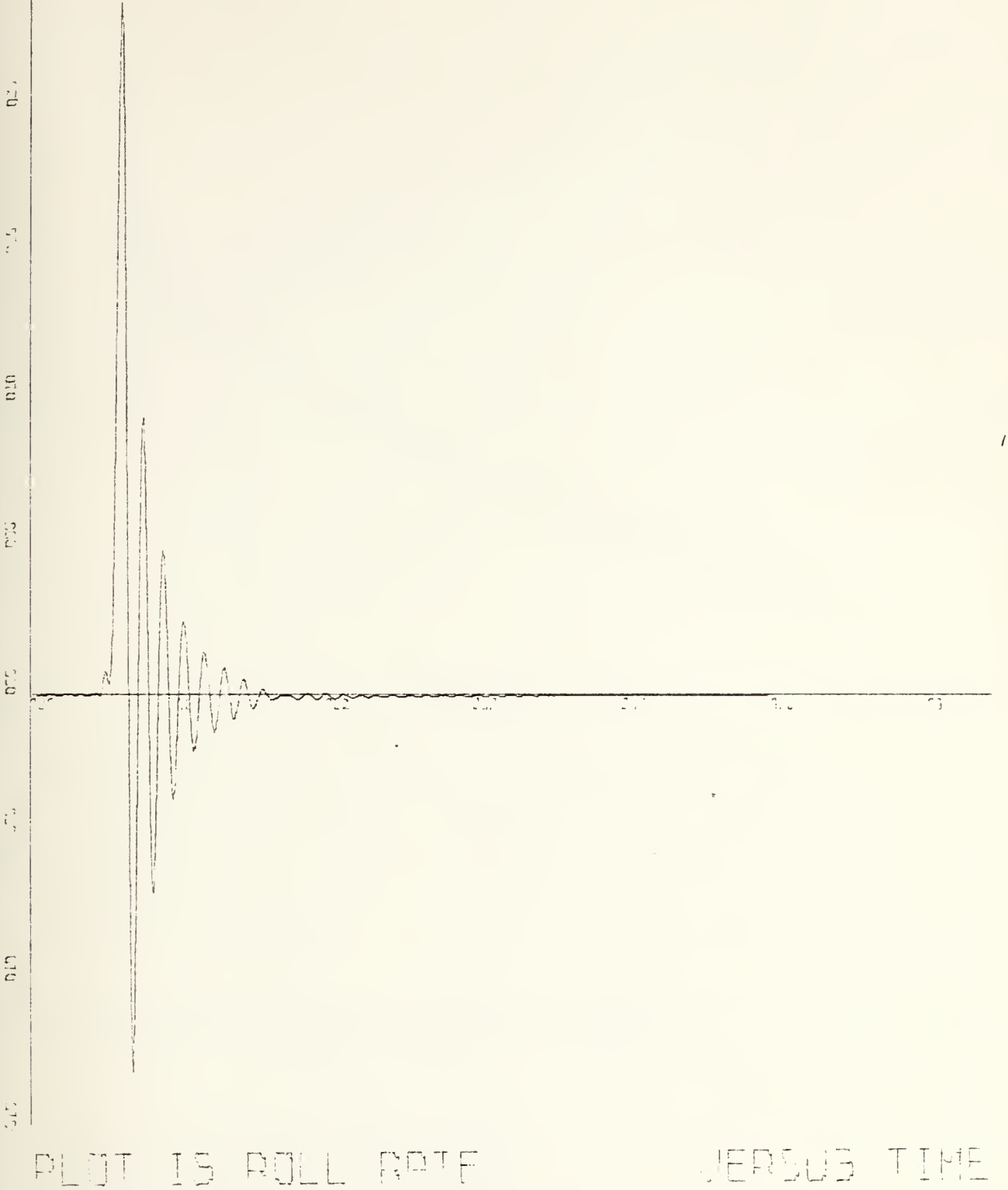


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

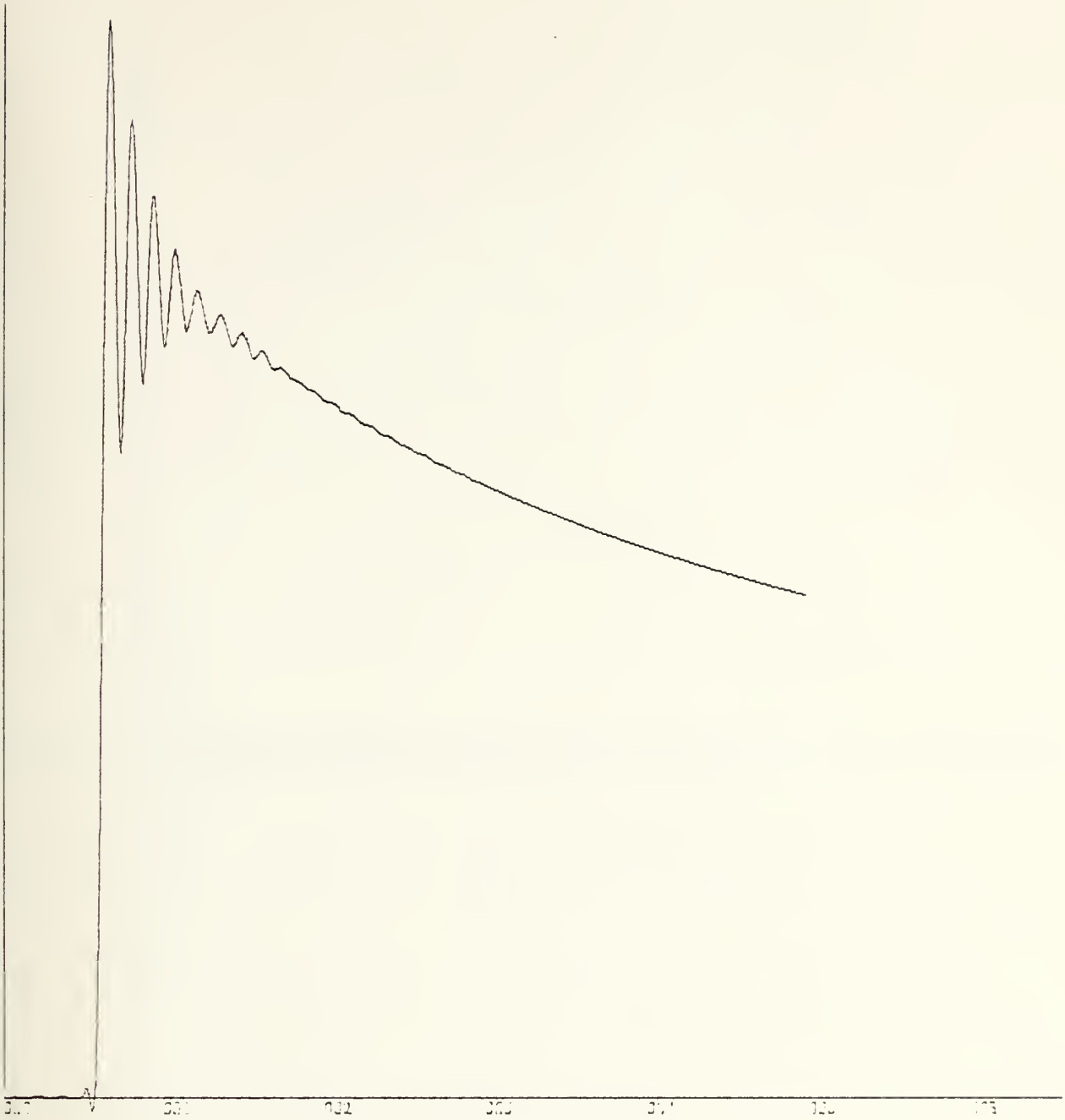
PLOT 75

for applied parameters see first page of this appendix



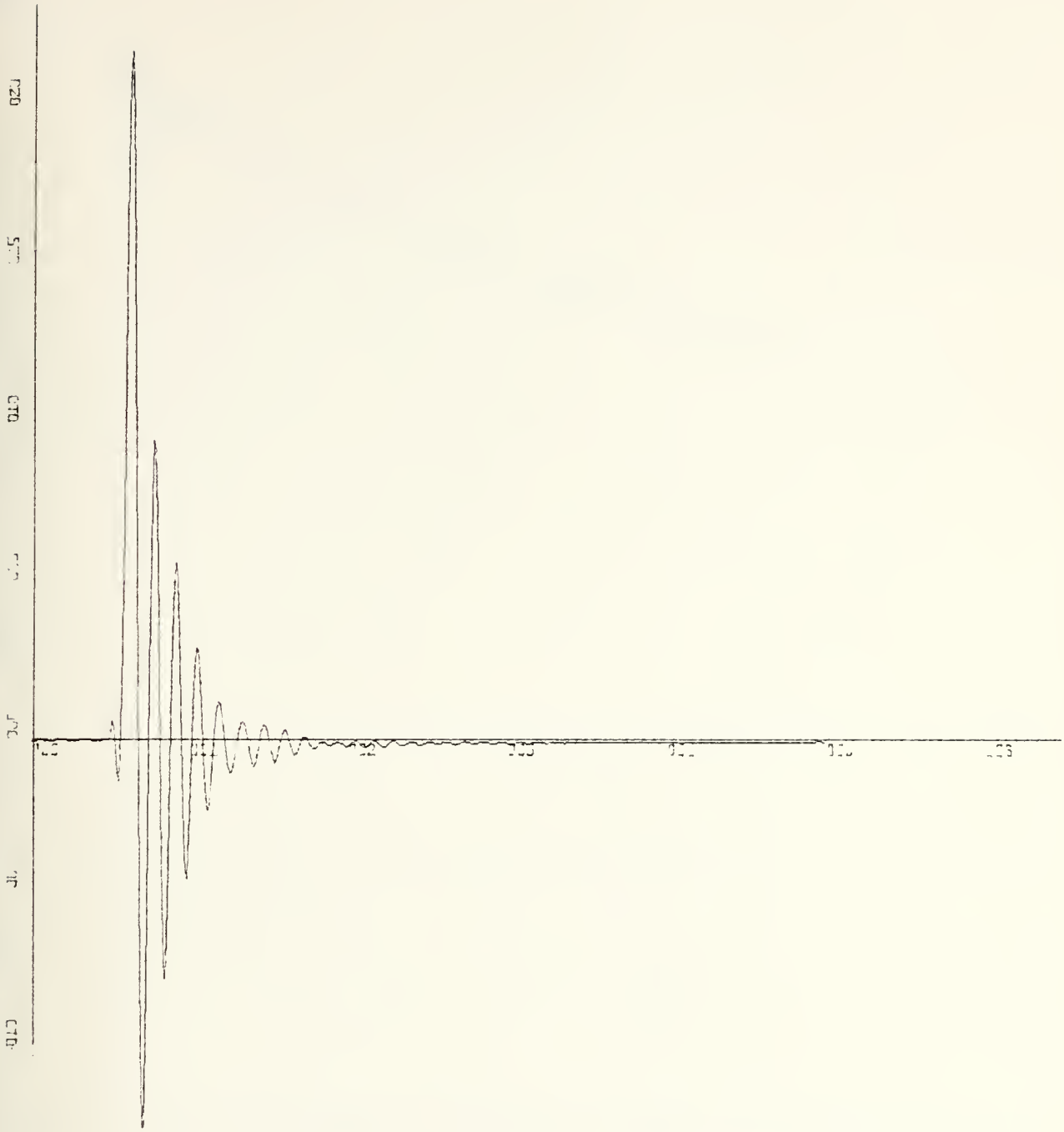
PLOT 76

for applied parameters see first page of this appendix



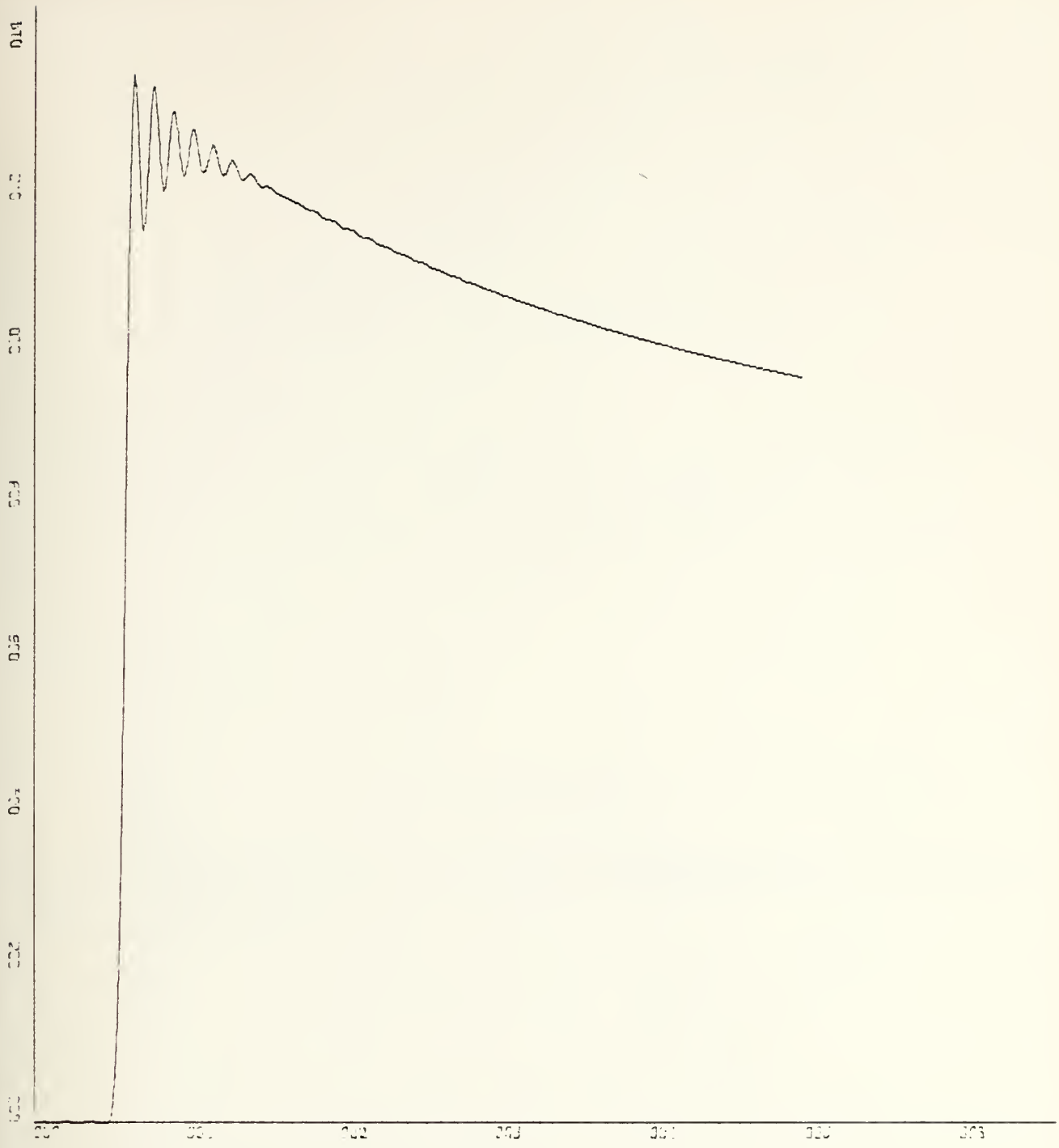
PLOT 77

for applied parameters see first page of this appendix



PLOT 78

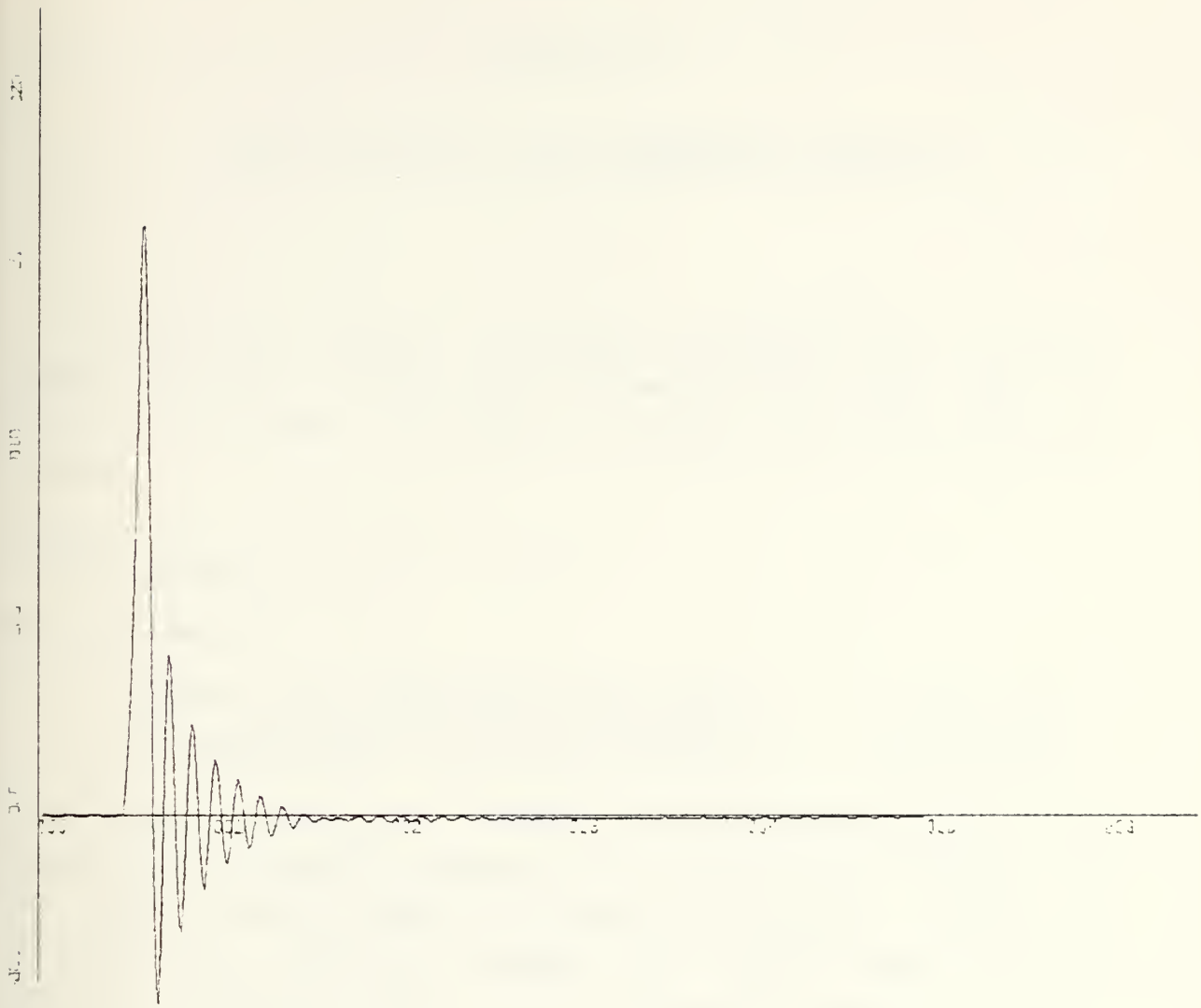
for applied parameters see first page of this appendix



X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 2.00E-01 UNITS INCH.
RCR1K3 . TURN 20 KN . RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 79

for applied parameters see first page of this appendix



PLOT 80

for applied parameters see first page of this appendix

APPENDIX B

MODIFICATIONS OF THE SIMULATION PROGRAM

During the course of studies undertaken with the XR-3 Loads and Motion Program some statements have been added or changed in order to improve the work with the simulation program.

* MAIN program

The statements

```
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT        (MAIN0050)
      IF (MYTIME(DUM).LT.IQUIT) GO TO 12        (MAIN0661)
```

have been modified and added to the MAIN-program. The purpose of the second statement is to start the writing of the output values desired if computer time has reached the demanded time (jobcard) reduced by IQUIT which is the expected amount of time (in 10^{-4} seconds) required to print the output. The user may input the desired value of IQUIT as the fourth parameter (I10-Format, columns 36-45) on the 107 data card. Default value for IQUIT is 600000 (60 seconds).

* Subroutine INCON

The added statements are

```
      IQUIT=600000                              (INCN0881)
```

to set the default value and

```
      READ (5,2041) IQUIT                       (INCN1455)
```

to read the set value for IQUIT thereby overriding the default value.

* Subroutine RHS

In Menzel's version [Ref. 2] of the XR-3 Loads and Motions Program the entered craft's velocity UO (kn) is changed in Subroutine INCON to U (ft/sec) by

```
U = UO*1.6889                    (INCN4580)
```

and in Subroutine RHS transformed back to units in knots (RHS 1850) by

```
VEL = 0.5925*U .                 (RHS 1850)
```

From these two equations follows

```
VEL = 0.5925*UO*1.6889
```

and for UO=20 kn there results VEL = 20.0135 kn . But since it is desired that VEL=UO the statement has been corrected to

```
VEL = U/1.6889 .
```

Statements MAIN0840, RHS 1140 have been changed accordingly.

* Subroutine INTGRL

To this subrcutine the statement

```
CALL COLFIL                      (INT 1021)
```

has been added in order to provide the output values already calculated to the user if the minimum time interval allowed in the integration process is undergone. Before this addition only the warning message

```
'DELTA TIME LESS THAN 1.0E-6 - - JOB STOPS'
```

appeared and the output values have been lost.

APPENDIX C

XR-3 LOADS AND MOTIONS PROGRAM

```
C                                                                       MAIN0010
CC     MAIN DECK                                                        MAIN0020
C                                                                       MAIN0030
       INTEGER ON                                                       MAIN0040
       COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                               MAIN0050
       COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IYMAIN0060
       COMMON /CONST/ PI,RAD,UO                                         MAIN0070
       COMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,    MAIN0080
      ATIP(25),TIS(25)                                                  MAIN0090
       COMMON /EQNCO/ NEQS,TCL(20),JQQ                                  MAIN0100
       COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP                           MAIN0110
       COMMON / FRCUDE / FN,FNCRIT                                      MAIN0120
       COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                    MAIN0130
       COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7 MAIN0140
       COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES, MAIN0150
      -IRUD,IPROP,IAEROD,IRHS                                           MAIN0160
       COMMON /ROLL/ PHIMAX,TROLL                                       MAIN0170
       COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR, MAIN0180
      ARCLB,RTC,RUDANG,TIR(25)                                          MAIN0190
       COMMON / VALOLD / YOLD(20)                                       MAIN0200
       COMMON /VARBLE/ VAL(40)                                          MAIN0210
       COMMON /WAVE/ ETA(4,11),AW(10),CMEGA(10),CVCLW,NWAVE,BETA,       MAIN0220
      1               FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV               MAIN0230
      2               ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR        MAIN0240
       EQUIVALENCE                (VAL(2),U),(VAL(3),V),(VAL(4),W),     MAIN0250
      1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),    MAIN0260
      2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),MAIN0270
      3(VAL(24),PB)                                                     MAIN0280
       DIMENSION DUMMY(20)                                              MAIN0290
C                                                                       MAIN0300
       TC=1.0                                                           MAIN0310
       CN=1                                                             MAIN0320
       PI=4.*ATAN(1.)                                                   MAIN0330
       RAD=180./PI                                                      MAIN0340
       WRITE(6,100)                                                     MAIN0350
 100   FORMAT(1H1//35X,22H LISTING OF INPUT DECK  //)                   MAIN0360
 99    READ(44,101,END=104) DUMMY                                       MAIN0370
 101   FORMAT(20A4)                                                     MAIN0380
 105   WRITE(6,102)DUMMY                                                MAIN0390
       WRITE(5,101) DUMMY                                               MAIN0400
 102   FORMAT(5X,20A4)                                                  MAIN0410
       GO TO 99                                                         MAIN0420
 104   REWIND 5                                                         MAIN0430
C                                                                       MAIN0440
 11    CALL INCON(TIME)                                                 MAIN0450
C                                                                       MAIN0460
       IF (IMM.EQ.3)  GO TO 605                                         MAIN0470
       DO 10 J=1,20                                                     MAIN0480
```

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   10   YCLD(J)=VAL(J+1)                                                    MAIN0490
        GO TO 2                                                             MAIN0500
    1   CONTINUE                                                            MAIN0510
        TOLD=TIME                                                           MAIN0520
        PBBAR=PBBAR*(1.-DELT/TC)+DELT*(PB-PINF)/TC                          MAIN0530
        IF ( NWAVE.LE.0 )  GO TO 13                                         MAIN0540
        ZBAR=(1.-DELT/TC)*ZBAR+DELT*Z/TC                                    MAIN0550
        PHIBAR=(1.-DELT/TC)*PHIBAR+DELT*PHI/TC                              MAIN0560
        THEBAR=(1.-DELT/TC)*THEBAR+DELT*THETA/TC                            MAIN0570
C                                                                           MAIN0580
        CALL WAVES(TIME)                                                    MAIN0590
   13   CALL SIDEWL                                                         MAIN0600
        CALL PROP                                                           MAIN0610
        CALL RUDDER                                                         MAIN0620
        CALL AEROD                                                          MAIN0630
        CALL INTGRL(TIME)                                                   MAIN0640
C                                                                           MAIN0650
        IF(TIME.GT.FTIME) GO TO 12                                          MAIN0660
        IF (MYTIME(DUM).LT.IQUIT) GO TO 12                                  MAIN0661
        IF ( FN.GT.FNCRIT) GO TO 14                                         MAIN0670
        PRINT 505                                                           MAIN0680
        GO TO 12                                                            MAIN0690
   14   DELOLD=TIME-TOLD                                                    MAIN0700
        PSI=PSI+DELCLD*R                                                    MAIN0710
        X=X+DELCLD*(U*COS(PSI)-V*SIN(PSI))                                  MAIN0720
        Y=Y+DELOLD*(U*SIN(PSI)+V*COS(PSI))                                  MAIN0730
   15   IF (ABS(TIME-TPRINT) .LT. 1.E-6) GO TO 2                            MAIN0740
        GO TO 1                                                             MAIN0750
   2    CONTINUE                                                            MAIN0760
        IF(ITRAJ .EQ. 0) GOTO 16                                            MAIN0770
        DPHI=PHI*RAD                                                        MAIN0780
        DPSI=PSI*RAD                                                        MAIN0790
        DTHETA=THETA*RAD                                                    MAIN0800
        DP=P*RAD                                                            MAIN0810
        DQ=Q*RAD                                                            MAIN0820
        DR=R*RAD                                                            MAIN0830
        VEL=0.5925*U                                                        MAIN0840
        WRITE (6,500) TIME,VEL,V,W,DP,DQ,DR,Z,DPHI,DTHETA,X,Y,DPSI          MAIN0850
        BETS=(-V/U)*RAD                                                     MAIN0860
        DELRS=RUDANG*RAD                                                    MAIN0870
        WRITE(6,501) BETS,DELRS,FXP                                         MAIN0880
16      CONTINUE                                                            MAIN0890
        IMMTAG = (IMM+1)/2                                                  MAIN0900
        IF ( IMMTAG .EQ. 1  .AND. TIME.GE.BTIME-1.E-8 )  IMT = 1            MAIN0910
        TPRINT=TPRINT+DELPNT                                                MAIN0920
        CN=1                                                                MAIN0930
        GO TO 1                                                             MAIN0940
C                                                                           MAIN0950
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   12  CALL COLFIL                                                          MAIN0960
C                                                                           MAIN0970
       IF (IMM.LT.1)  GO TO 11                                              MAIN0980
       IF (IMM.NE.1)  GO TO 605                                             MAIN0990
       END FILE IBMFIL                                                      MAIN1000
       GO TO 11                                                             MAIN1010
C                                                                           MAIN1020
   605 CALL SAM                                                             MAIN1030
C                                                                           MAIN1040
       GO TO 11                                                             MAIN1050
C                                                                           MAIN1060
   500 FORMAT(//10X,13HTIME (SEC) =  F6.2//10X,33HTRANSLATIONAL VELS (KTSMAIN1070
      1)/(FT/SEC) /10X,2HU= F6.2,5X,2HV= F6.2,5X,2HW= F6.3//10X,31HROTATIMAIN1080
      2ONAL VELOCITIES (DEG/SEC) /10X,2HP= F6.2,5X,2HQ= F6.2,5X,2HR= F6.2MAIN1090
      3//10X,30HDISPLACEMENTS (FT AND DEGREES) /10X,2HZ= F7.3,5X,4HPHI=  MAIN1100
      4F6.2,3X,6HTHETA= F6.2//10X,27HTRAJECTORY (FT AND DEGREES) /10X,   MAIN1110
      52HX= F8.2,4X,2HY= F8.2,4X,4HPSI= F8.2)                           MAIN1120
   501 FORMAT(1HO,9X,23HSIDESLIP ANGLE (DEG) =   F8.2,10X,21HRUDDER ANGLEMAIN1130
      1 (DEG) =  F8.3,10X,15HTHRUST (LBS) =   F12.1)                    MAIN1140
   505 FORMAT(///25X,28HCRAFT SPEED BELOW HUMP SPEED )                  MAIN1150
C                                                                           MAIN1160
       END                                                                  MAIN1170

C                                                                           BLDA0010
       BLOCK DATA                                                           BLDA0020
C                                                                           BLDA0030
       COMMON /AIR/ Z1(4)                                                   BLDA0040
C    IN MAIN, INCON, SIDEWL, RHS, BOWSL, STNSL, FAN                         BLDA0050
       COMMON /BMCO/ Z2(25)                                                 BLDA0060
C    IN MAIN, INCON, WAVES, SIDEWL, RHS, INTGRL                             BLDA0070
       COMMON /COLUMN / Z3(2)                                               BLDA0080
C    IN INCON, RHS, COLFIL                                                  BLDA0090
       COMMON /CONST/ Z4(3)                                                 BLDA0100
C    IN MAIN, INCON, WAVES, SIDEWL, PROP, RUDDER, RHS, BOWSL, STNSL         BLDA0110
       COMMON /CNTRL/ Z5(10)                                                BLDA0120
C    IN INCON, RHS                                                          BLDA0130
       COMMON /ENGINE/ Z6(107)                                              BLDA0140
C    IN MAIN, INCON, PROP, RHS                                              BLDA0150
       COMMON /EQNCO/ Z7(22)                                                BLDA0160
C    IN MAIN, INCON, INTGRL, COLFIL                                         BLDA0170
       COMMON /FAERO/ Z8(6)                                                 BLDA0180
C    IN AEROD, RHS                                                          BLDA0190
       COMMON /FAIR/ Z9(2)                                                  BLDA0200
C    IN INCON, AEROD                                                        BLDA0210
       COMMON /FANMAP/ Z10(262)                                             BLDA0220
C    IN INCON, RHS, FAN                                                     BLDA0230
       COMMON /FORBS/ Z11(7)                                                BLDA0240
C    IN RHS, BOWSL                                                          BLDA0250
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      COMMON /FORSS/Z12(8)                                                    BLDA0260
C     IN RHS, STNSL                                                           BLDA0270
      COMMON /FPRCP/ Z13(6)                                                   BLDA0280
C     IN MAIN, PROP, RHS                                                      BLDA0290
      COMMON /FROUDE/ Z14(2)                                                  BLDA0300
C     IN MAIN, INCON, RHS                                                     BLDA0310
      COMMON /FRUD/ Z15(6)                                                    BLDA0320
C     IN RUDDER, RHS                                                          BLDA0330
      COMMON /GBOW/ Z16(1)                                                    BLDA0340
C     IN INCON, RHS                                                           BLDA0350
      COMMON /GEOM/ Z17(138)                                                  BLDA0360
C     IN INCON, WAVES, SIDEWL, RHS, BOWSL, STNSL                              BLDA0370
      COMMON /GEOMBS/ Z18(62)                                                 BLDA0380
C     IN WAVES, RHS, BOWSL                                                    BLDA0390
      COMMON /GEOMSS/ Z19(62)                                                 BLDA0400
C     IN WAVES, RHS, STNSL                                                    BLDA0410
      COMMON /GEOMSW/ Z20(11)                                                 BLDA0420
C     IN INCON, SIDEWL                                                        BLDA0430
      COMMON /KSWTCH/ Z21(1)                                                  BLDA0440
C     IN SIDEWL, RHS, STNSL, INTGRL                                           BLDA0450
      COMMON /LEAKER/ Z22(4)                                                  BLDA0460
C     IN INCON, BOWSL, STNSL                                                  BLDA0470
      COMMON /MASSES/ Z23(817)                                                BLDA0480
C     IN INCON, WAVES, SIDEWL, RUDDER, RHS, BOWSL, STNSL, INTGRL              BLDA0490
      COMMON /MATRIX/ Z24(36)                                                 BLDA0500
C     IN INCON, RHS                                                           BLDA0510
      COMMON /MSIDW/ Z25(55)                                                  BLDA0520
C     IN SIDEWL, RHS                                                          BLDA0530
      COMMON /MWAVE/ Z26(12)                                                  BLDA0540
C     IN WAVES, RHS                                                           BLDA0550
      COMMON /OPTION/ Z27(5)                                                  ********
C     IN INCON, RHS                                                           BLDA0570
      COMMON /PLENUM/ Z28(4)                                                  BLDA0580
C     IN INCON, WAVES, SIDEWL, RHS                                            BLDA0590
      COMMON /PRIME/ Z29(5)                                                   BLDA0600
C     IN MAIN, INCON, SIDEWL, RHS, INTGRL                                     BLDA0610
      COMMON /PRTINT/ Z30(12)                                                 BLDA0620
C     IN MAIN, INCON, WAVES, SIDEWL, PROP, RUDDER, AEROD, RHS, BOWSL,         BLDA0630
C        STNSL, FAN, INTGRL                                                   BLDA0640
      COMMON /PWAVE/ Z31(2)                                                   BLDA0650
C     IN INCON, RHS                                                           BLDA0660
      COMMON /RISER/ Z32(1)                                                   BLDA0670
C     IN INCON, WAVES                                                         BLDA0680
      COMMON /ROLL/ Z33(2)                                                    BLDA0690
C     IN MAIN, INCON                                                          BLDA0700
      COMMON /RUDDR/ Z34(62)                                                  BLDA0710
C     IN MAIN, INCON, PROP, RUDDER, RHS                                       BLDA0720
      COMMON /SIDE/ Z35(22)                                                   BLDA0730
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C     IN INCON, WAVES, SIDEWL, RHS                                                    BLDA0740
        COMMON /SOFTBS/ Z36(20)                                                       BLDA0750
C     IN INCON, RHS, BOWSL, FAN                                                       BLDA0760
        COMMON /SOFTSS/ Z37(19)                                                       BLDA0770
C     IN INCON, RHS, STNSL, FAN                                                       BLDA0780
        COMMON /STABLE/ Z38(5)                                                        BLDA0790
C     IN INCON, INTGRL                                                                BLDA0800
        COMMON /STSLR/ Z39(2)                                                         BLDA0810
C     IN INCON, STNSL                                                                 BLDA0820
        COMMON /VALOLD/ Z40(20)                                                       BLDA0830
C     IN MAIN, INCON, RHS, STNSL, INTGRAL                                             BLDA0840
        COMMON /VARBLE/ Z41(40)                                                       BLDA0850
C     IN MAIN, INCON, WAVES, SIDEWL, PROP, RUDDER, AEROD, RHS, BOWSL,                 BLDA0860
C        STNSL, FAN, INTGRL                                                           BLDA0870
        COMMON /WAVE/ Z42(80)                                                         BLDA0880
C     IN MAIN, INCON, WAVES, SIDEWL, RHS, BOWSL, STNSL                                BLDA0890
        COMMON /WAVEF / Z43(40)                                                       BLDA0900
C     IN INCON                                                                        BLDA0910
        COMMON /SLOPE/Z44(5)                                                          BLDA0920
C     IN INCON, RHS, BOWSL                                                            BLDA0930
        COMMON /PROMOD/ Z45(7)                                                        BLDA0940
C     IN MAIN AND ALL SUBROUTINES                                                     BLDA0950
C                                                                                     BLDA0960
        DATA Z1/4*0.0/                                                                BLDA0970
        DATA Z2/25*0.0/                                                               BLDA0980
        DATA Z3/2*0.0/                                                                BLDA0990
        DATA Z4/3*0.0/                                                                BLDA1000
        DATA Z5/10*0.0/                                                               BLDA1010
        DATA Z6/107*0.0/                                                              BLDA1020
        DATA Z7/21*0.0/                                                               BLDA1030
        DATA Z8/6*0.0/                                                                BLDA1040
        DATA Z9/2*0.0/                                                                BLDA1050
        DATA Z10/262*0.0/                                                             BLDA1060
        DATA Z11/7*0.0/                                                               BLDA1070
        DATA Z12/8*0.0/                                                               BLDA1080
        DATA Z13/6*0.0/                                                               BLDA1090
        DATA Z14/2*0.0/                                                               BLDA1100
        DATA Z15/6*0.0/                                                               BLDA1110
        DATA Z16/0.0/                                                                 BLDA1120
        DATA Z17/138*0.0/                                                             BLDA1130
        DATA Z18/62*0.0/                                                              BLDA1140
        DATA Z19/62*0.0/                                                              BLDA1150
        DATA Z20/11*0.0/                                                              BLDA1160
        DATA Z21/0.0/                                                                 BLDA1170
        DATA Z22/4*0.0/                                                               BLDA1180
        DATA Z23/817*0.0/                                                             BLDA1190
        DATA Z24/36*0.0/                                                              BLDA1200
        DATA Z25/55*0.0/                                                              BLDA1210
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      DATA Z26/12*0.0/                                                  BLDA1220
      DATA Z27/5*0.0/                                                   ********
      DATA Z28/4*0.0/                                                   BLDA1240
      DATA Z29/5*0.0/                                                   BLDA1250
      DATA Z30/12*0.0/                                                  BLDA1260
      DATA Z31/2*0.0/                                                   BLDA1270
      DATA Z32/0.0/                                                     BLDA1280
      DATA Z33/2*0.0/                                                   BLDA1290
      DATA Z34/62*0.0/                                                  BLDA1300
      DATA Z35/22*0.0/                                                  BLDA1310
      DATA Z36/20*0.0/                                                  BLDA1320
      DATA Z37/19*0.0/                                                  BLDA1330
      DATA Z38/5*0.0/                                                   BLDA1340
      DATA Z39/2*0.0/                                                   BLDA1350
      DATA Z40/20*0.0/                                                  BLDA1360
      DATA Z41/40*0.0/                                                  BLDA1370
      DATA Z42/80*0.0/                                                  BLDA1380
      DATA Z43/40*0.0/                                                  BLDA1390
      DATA Z44/5*0.0/                                                   BLDA1400
      DATA Z45/7*0.0/                                                   BLDA1410
C                                                                       BLDA1420
      END                                                               BLDA1430
C
C                                                                       AER 0010
      SUBROUTINE AEROD                                                  AER 0020
C                                                                       AER 0030
                                                                        AER 0040
      INTEGER ON                                                        AER 0050
      COMMON /FAERO/ FX,FY,FZ,FK,FM,FN                                  AER 0060
      COMMON /FAIR/ RHOA,XLAERO                                         AER 0070
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  AER 0080
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,  AER 0090
     -IRUD,IPROP,IAEROD,IRHS                                            AER 0100
      COMMON /VARBLE/ VAL(40)                                           AER 0110
      EQUIVALENCE                (VAL(2),U),(VAL(3),V),(VAL(4),W),      AER 0120
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),     AER 0130
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),AER 0140
     3(VAL(24),PB)                                                      AER 0150
C                                                                       AER 0160
      QA=RHOA*U*U                                                       AER 0170
      QAL=QA*XLAERO                                                     AER 0180
      BETA=-V/U                                                         AER 0190
      BETASQ=BETA*BETA                                                  AER 0200
      FX=-(0.90*BETASQ+0.13)*QA                                         AER 0210
      FY=(0.0*BETASQ+0.53*BETA)*QA                                      AER 0220
      FZ=-(2.06*BETASQ+0.39)*QA                                         AER 0230
      FK=-(0.5*BETASQ+0.0*BETA)*QAL                                     AER 0240
      FM=(0.29*BETASQ+0.12)*QAL                                         AER 0250
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      FN=(0.0*BETASQ+0.076*BETA)*QAL                                    AER 0260
      IF (IAEROD.NE.ON) RETURN                                          AER 0270
                        WRITE(6,100) FX,FY,FZ,FK,FM,FN                  AER 0280
C                                                                       AER 0290
  100 FORMAT(/10X,23HAEROD FX,FY,FZ,FK,FM,FN/6E15.4)                    AER 0300
C                                                                       AER 0310
      RETURN                                                            AER 0320
      END                                                               AER 0330

C                                                                       BWSL0010
      SUBROUTINE BOWSL                                                  BWSL0020
C                                                                       BWSL0030
      INTEGER ON                                                        BWSL0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                BWSL0050
      COMMON /CONST/ PI,RAD,UO                                          BWSL0060
      COMMON /FORBS/ FX,FY,FZ,FK,FM,FN,CL                               BWSL0070
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,BWSL0080
     1IO),XCP,ZCP                                                       BWSL0090
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)BWSL0100
     1,ISKIB(10)                                                        BWSL0110
      COMMON /LEAKER/ ALEAK,BLEAK,CFSS,CFBS                             BWSL0120
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMBWSL0130
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                         BWSL0140
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IBWSL0150
     1RUD,IPROP,IAEROD,IRHS                                             BWSL0160
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  BWSL0170
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                    BWSL0180
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVBWSL0190
     1GE(10),CENCAB                                                     BWSL0200
      COMMON /VARBLE/ VAL(40)                                           BWSL0210
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVCLW,NWAVE,BETA,FXWAV,FYBWSL0220
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBWSL0230
     2BAR                                                               BWSL0240
      DIMENSION ELSKID(11), WETLEN(11), BWSL(6,24), GAP(11), ELSKI(11), BWSL0250
     1DPFT(11), WTAB(6), ZTAB(6)                                        BWSL0260
      DATA NPTS,IBS/6,0/                                                BWSL0270
      DATA WTAB/0.0,3.75,5.42,6.67,7.5,8.42/                            BWSL0280
      DATA ZTAB/3.75,4.00,4.42,4.83,5.25,5.67/                          BWSL0290
      DATA ENU,UWSKI,CLSKI,HINGHT/1.28E-05,0.0,1.5708,1.875/            BWSL0300
      DATA BWSL/0.0,3.8,6.9,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.0BWSL0310
     1,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12.BWSL0320
     24,15.4,18.3,0.0,5.5,9.6,13.3,16.1,19.6,0.0,5.8,9.9,13.8,17.1,20.6,BWSL0330
     30.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,11BWSL0340
     4.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,24BWSL0350
     5.1,28.3,0.0,8.2,15.3,21.7,26.3,31.3,0.0,9.6,17.5,24.2,29.7,34.6,0.BWSL0360
     60,11.9,20.0,26.7,32.3,38.0,0.0,14.0,22.5,30.0,35.8,41.0,0.0,17.5,2BWSL0370
     75.5,32.5,39.7,44.5,0.0,21.0,30.0,37.4,42.0,47.0,0.0,24.6,33.7,41.0BWSL0380
     8,45.0,48.7,0.0,29.4,38.5,45.0,48.7,48.7,0.0,33.0,45.0,48.7,48.7,48BWSL0390
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     9.7,0.0,40.0,48.7,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,4BWSL0400
     $8.7,48.7,48.7,48.7,48.7/                                                BWSL0410
      DATA CORLEN/3.75/                                                       BWSL0420
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VABWSL0430
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VABWSL0440
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)BWSL0450
     3, (VAL(24),PB)                                                          BWSL0460
C                                                                             BWSL0470
      DO 1 J=1,11                                                             BWSL0480
      GAP(J) = 0.0                                                            BWSL0490
      ELSKI(J) = 0.0                                                          BWSL0500
      WETLEN(J) = 0.0                                                         BWSL0510
      ELSKID(J) = 0.0                                                         BWSL0520
    1 CONTINUE                                                                BWSL0530
      ALBS = 0.0                                                              BWSL0540
      FX = 0.0                                                                BWSL0550
      FZ = 0.0                                                                BWSL0560
      FK = 0.0                                                                BWSL0570
      FM = 0.0                                                                BWSL0580
      FN = 0.0                                                                BWSL0590
      DELPBG = PBS-PB                                                         BWSL0600
      IF (DELPBG.LT.0.0) DELPBG=0.0                                           BWSL0610
      PBAR = PB-PINF                                                          BWSL0620
      DELP = PBAR                                                             BWSL0630
      IF (DELP.LT.0.0) DELP=0.0                                               BWSL0640
      ARGO = ELMAXB/CORLEN                                                    BWSL0650
      ANGO = ARSIN(ARGO)                                                      BWSL0660
      X1 = XBS+ZBS*THETA-CORLEN*COS(ANGO)                                     BWSL0670
      Z1 = -Z-ZBS+XBS*THETA-ELMAXB*COS(THETA)                                 BWSL0680
      DPTHFT = (5.5/(1.+(U/25.))**2.0)/12.0                                   BWSL0690
      IF (CENCAB.GT.1.1875) CENCAB=1.1875                                     BWSL0700
      N = NSTA(3)                                                             BWSL0710
      DO 3 K=1,N                                                              BWSL0720
      DPFT(K) = DPTHFT                                                        BWSL0730
      ELSKI(K) = (ETA(3,K)-DETABX(K)*(XX(3,K)-X1)-Z1)+YY(3,K)*PHI+XLXPWVBWSL0740
     1*WATSLP                                                                 BWSL0750
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT                                 BWSL0760
      IF ((HINGHT-ELSKI(K)+DPFT(K)).GE.ELMAXB) DPFT(K)=ELMAXB-HINGHT+ELSBWSL0770
     1KI(K)                                                                   BWSL0780
      IF (DPFT(K).LT.0.0) DPFT(K)=0.0                                         BWSL0790
      ELSKID(K) = (ELSKI(K)-DPFT(K))*12.0                                     BWSL0800
      IF ((HINGHT-ELSKID(K)/12.0).GE.ELMAXB) ELSKID(K)=(HINGHT-ELMAXB)*1BWSL0810
     12.0                                                                     BWSL0820
      DPIN = DPFT(K)*12.0                                                     BWSL0830
      MM = DPIN                                                               BWSL0840
      MM1 = MM+1                                                              BWSL0850
      MM2 = MM1+1                                                             BWSL0860
      DINC = DPIN-MM                                                          BWSL0870
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      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXB)                                BWSL0880
      IF (GAP(K).LT.0.0) GAP(K)=0.0                                     BWSL0890
      IF (ELSKID(K).GE.0.) GO TO 2                                      BWSL0900
      WETLEN(K) = ELSKI(K)                                              BWSL0910
      GO TO 3                                                           BWSL0920
    2 MM3 = ELSKID(K)                                                   BWSL0930
      MM4 = MM3+1                                                       BWSL0940
      MM5 = MM4+1                                                       BWSL0950
      DLINC = ELSKID(K)-MM3                                             BWSL0960
      BWSL1 = BWSL(MM1,MM4)                                             BWSL0970
      BWSL2 = BWSL(MM1,MM5)                                             BWSL0980
      BWSL3 = BWSL(MM2,MM4)                                             BWSL0990
      BWSL4 = BWSL(MM2,MM5)                                             BWSL1000
      BWSLA1 = (BWSL2-BWSL1)*DLINC+BWSL1                                BWSL1010
      BWSLA2 = (BWSL4-BWSL3)*DLINC+BWSL3                                BWSL1020
      WETLEN(K) = ((BWSLA2-BWSLA1)*DINC+BWSLA1)/12.0                    BWSL1030
    3 CONTINUE                                                          BWSL1040
      N = NSTA(3)-1                                                     BWSL1050
      DO 10 J=1,N                                                       BWSL1060
      WETLAV = (WETLEN(J+1)+WETLEN(J))/2.0                              BWSL1070
      IF (WETLAV.LE.0.001) GO TO 8                                      BWSL1080
      DPFTAV = (DPFT(J+1)+DPFT(J))/2.0                                  BWSL1090
      ELSKIA = (ELSKI(J+1)+ELSKI(J))/2.0                                BWSL1100
      ELSKDA = (ELSKID(J+1)+ELSKID(J))/24.0                             BWSL1110
      SEALHT = HINGHT-ELSKDA                                            BWSL1120
      DIFF = 2.0*CENCAB-(SEALHT+0.5)                                    BWSL1130
      IF (DIFF.GT.0.5) DIFF=0.5                                         BWSL1140
      ARM1B(J) = X1+WETLAV/2.0                                          BWSL1150
      ARM2B(J) = ZS-ELSKIA+DPFTAV/2.0                                   BWSL1160
      IF (DIFF.GE.0.25) GO TO 4                                         BWSL1170
      DFBS(J) = -DELP*DELYBS*WETLAV                                     BWSL1180
      GO TO 7                                                           BWSL1190
    4 FORLEN = XBF-WETLAV                                               BWSL1200
      IF (FORLEN.EQ.0.0) GO TO 5                                        BWSL1210
      ARGW = (HINGHT-ELSKIA)/FORLEN                                     BWSL1220
      IF (ARGW.GT.1.0) ARGW=1.0                                         BWSL1230
      ANGW = ARSIN(ARGW)                                                BWSL1240
      FORCOS = COS(ANGW)                                                BWSL1250
      GO TO 6                                                           BWSL1260
    5 FORCOS = 0.0                                                      BWSL1270
    6 DFBS(J) = -DELP*DELYBS*WETLAV-DELP*FORLEN*DELYBS*FORCOS*((FORLEN*0BWSL1280
     1.5*FORCOS)/(FORLEN*FORCOS+WETLAV/2.0))*((DIFF-0.25)*4.0)          BWSL1290
    7 ARG = 0.5*RHO*U*U*WETLAV*DELYBS                                   BWSL1300
      RESKI = U*WETLAV/ENU                                              BWSL1310
      CDTSKI = 0.427/(ALOG10(RESKI)-0.407)**2.64                        BWSL1320
      TSKIB(J) = -ARG*CDTSKI                                            BWSL1330
      GO TO 9                                                           BWSL1340
    8 DFBS(J) = 0.0                                                     BWSL1350
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      TSKIB(J) = 0.0                                                    BWSL1360
    9 CONTINUE                                                          BWSL1370
      FX = FX+TSKIB(J)                                                  BWSL1380
      FZ = FZ+DFBS(J)                                                   BWSL1390
      FK = FK+DFBS(J)*YAVGB(J)                                          BWSL1400
      FM = FM-DFBS(J)*ARM1B(J)+TSKIB(J)*ARM2B(J)                        BWSL1410
      FN = FN-TSKIB(J)*YAVGB(J)                                         BWSL1420
      ALBS = ALBS+(GAP(J)+GAP(J+1))*DELYBS/2.0                          BWSL1430
   10 CONTINUE                                                          BWSL1440
      ALBS = ALBS+BLEAK                                                 BWSL1450
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)                                 BWSL1460
      CL = CFBS*ALBS*SQFAC*SIGN(1.,PBAR)                                BWSL1470
      IF (IBOWSL.NE.ON) RETURN                                          BWSL1480
      WRITE (6,11) GAP,WETLEN,FX,FY,FZ,FK,FM,FN                         BWSL1490
C                                                                       BWSL1500
   11 FORMAT (//10X,8HBOW SEAL/26H GAP (FT.) (PORT TO STBD.)/11F10.5/28HBWSL1510
     1 WETLEN(FT.) (PORT TO STBD.)/11F10.5/10X,23HBOWSL FX,FY,FZ,FK,FM,FBWSL1520
     2N/6E15.4)                                                         BWSL1530
C                                                                       BWSL1540
      RETURN                                                            BWSL1550
      END                                                               BWSL1560

C                                                                       CFL 0010
      SUBROUTINE COLFIL                                                 CFL 0020
C                                                                       CFL 0030
      COMMON/AXIS/NXYS(26)                                              CFL 0040
      COMMON/COLUMN/IVERT,ILATRL                                        CFL 0050
      COMMON /CURVE/NCURV(10)                                           CFL 0060
      COMMON/EQNCO/ NEQS,TCL(20),JQQ                                    CFL 0070
      COMMON/GRAF/NGRAF,NDRW                                            CFL 0080
      COMMON /HEADG/TICRD(6)                                            CFL 0090
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7. CFL 0100
      COMMON/STEP/ STEP2                                                CFL 0110
      COMMON /SUM/ ISUM1(8),ISUM2(8)                                    CFL 0120
      REAL*8 TICRD                                                      CFL 0130
      REAL LABEL                                                        CFL 0140
      REAL LAB(4)/'    ',   1',   2',   3'/                            CFL 0150
      REAL*8 NAMES(52)/'TIME    ','          ','AIR MASS',' (BMASS)','Z DICFL 0160
     1SPLA','CEMENT  ','PITCH AN','GLE     ','PLENUM P','RESSURE ','BOW CFL 0170
     2ACCE','LERATION','C.G.ACCE','LERATION','FAN POWE','R(IDEAL)','BOWCFL 0180
     3 SEAL','PRESSURE','STN SEAL','PRESSURE','   WAVE ','HEIGHT  ','SPECFL 0190
     4EC TH','RU WATER','ROLL RAT','E       ','PLENUM V','OLUME   ','X DCFL 0200
     5ISPLA','CEMENT  ','Y DISPLA','CEMENT  ','AIR FLOW',' IN     ','AIRCFL 0210
     6 FLOW',' OUT    ','NET FORC','E X DIR ','WAVE FOR','CE X DIR','THRCFL 0220
     7UST S','TARBOARD','THRUST P','ORT SIDE','  PITCH ','RATE    ','STECFL 0230
     8RN SE','AL LIFT ','STERN SE','AL DRAG ','  ROLL A','NGLE    '/    CFL 0240
      REAL*8 TITLE(12)                                                  CFL 0250
      REAL*8 LINE2(2)/'PLOT IS ',' VERSUS '/                            CFL 0260
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      REAL*8 NAMEX(2),NAMEY(2),INAME(16)                                CFL 0270
      EQUIVALENCE (TITLE(1),TICRD(1)),(TITLE(2),TICRD(2)),(TITLE(3),TI  CFL 0280
     1CRD(3)),(TITLE(4),TICRD(4)),(TITLE(5),TICRD(5)),(TITLE(6),TICRD(  CFL 0290
     26))                                                               CFL 0300
      DIMENSION PVQQ(26),XOUT(900),YOUT(900),AFILE(8)                   CFL 0310
      DIMENSION THSTS(1), THSTP(1)                                      CFL 0320
      EQUIVALENCE (PVQQ(1),TIME),(PVQQ(2),BMASS),(PVQQ(3),Z),(PVQQ(4),THCFL 0330
     1ETA),(PVQQ(5),PBAR),(PVQQ(6),BOWACC),(PVQQ(7),ACC),(PVQQ(8),FANPWRCFL 0340
     2),(PVQQ(9),PBARB),(PVQQ(10),PBARS),(PVQQ(11),ETA),(PVQQ(12),U),(PVCFL 0350
     3QQ(13),PDEG),(PVQQ(14),VOLP),(PVQQ(15),X),(PVQQ(16),Y),(PVQQ(17),QCFL 0360
     4IN),(PVQQ(18),QOUT),(PVQQ(19),GFXXX),(PVQQ(20),FXPWAV),(PVQQ(21),TCFL 0370
     5HSTS(1)),(PVQQ(22),THSTP(1)),(PVQQ(23),QDEG),(PVQQ(24),FZSS),(PVQQCFL 0380
     6(25),FXSS),(PVQQ(26),PHI)                                         CFL 0390
C                                                                       CFL 0400
      IF(JQQ.NE.2) GO TO 1                                              CFL 0410
      WRITE(6,777) STEP2                                                CFL 0420
  777 FORMAT('0',4X,'THIS RUN USED VARIABLE STEP SIZE',/,'0',4X,'THE MINCFL 0430
     1IMUM STEPSIZE RECORDED DURING THE RUN WAS',2X,E30.5)              CFL 0440
    1 ENDFILE 1                                                         CFL 0450
      REWIND 1                                                          CFL 0460
      TITLE(7)=LINE2(1)                                                 CFL 0470
      TITLE(10)=LINE2(2)                                                CFL 0480
      IF(NGRAF.EQ.0) GO TO 11                                           CFL 0490
      J=1                                                               CFL 0500
      NGF=NGRAF                                                         CFL 0510
      INDEX=NGRAF*2                                                     CFL 0520
      DO 19 I=1,INDEX,2                                                 CFL 0530
      INDX=NXYS(I)                                                      CFL 0540
      INDY=NXYS(I+1)                                                    CFL 0550
      IQ=0                                                              CFL 0560
    7 READ(1,END=8)TIME,BMASS,Z,THETA,PBAR,BOWACC,ACC,FANPWR,PBARB,PBARSCFL 0570
     1,ETA,U,PDEG,VOLP,X,Y,GIN,QOUT,GFXXX,FXPWAV,THSTS(1),THSTP(1),QDEG,CFL 0580
     2FZSS,FXSS,PHI                                                     CFL 0590
      IF(IQ.GE.900) GO TO 8                                             CFL 0600
      IQ=IQ+1                                                           CFL 0610
      XOUT(IQ)=PVQQ(INDX)                                               CFL 0620
      YOUT(IQ)=PVQQ(INDY)                                               CFL 0630
      GO TO 7                                                           CFL 0640
    8 REWIND 1                                                          CFL 0650
      INX=INDX*2                                                        CFL 0660
      INY=INDY*2                                                        CFL 0670
      NAMEX(1)=NAMES(INX-1)                                             CFL 0680
      NAMEX(2)=NAMES(INX)                                               CFL 0690
      NAMEY(1)=NAMES(INY-1)                                             CFL 0700
      NAMEY(2)=NAMES(INY)                                               CFL 0710
      IF(NDRW.EQ.1) GO TO 20                                            CFL 0720
C                                                                       CFL 0730
      CALL PLOTP(XOUT,YOUT,-IQ,0)                                       CFL 0740
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C                                                                               CFL 0750
      WRITE(6,301) NAMEX,NAMEY                                                  CFL 0760
  301 FORMAT(' ',20X,2A8,' IS THE INDEPENDENT VARIABLE AND ',2A8,' THE DCFL 0770
     1EPENDENT VARIABLE')                                                       CFL 0780
      GO TO 19                                                                  CFL 0790
   20 TITLE(8)=NAMEY(1)                                                         CFL 0800
      TITLE(9)=NAMEY(2)                                                         CFL 0810
      TITLE(11)=NAMEX(1)                                                        CFL 0820
      TITLE(12)=NAMEX(2)                                                        CFL 0830
      NCUR=NCURV(J)                                                             CFL 0840
      IF(NCUR.NE.0) GO TO 25                                                    CFL 0850
      LABEL=LAB(1)                                                              CFL 0860
C                                                                               CFL 0870
      CALL DRAW(IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)         CFL 0880
C                                                                               CFL 0890
      J=J+1                                                                     CFL 0900
      GO TO 19                                                                  CFL 0910
   25 WRITE(2)IQ,NCUR,NGF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(L),L=1,ICFL 0920
     1Q)                                                                        CFL 0930
      NGF=NGF-1                                                                 CFL 0940
   19 CONTINUE                                                                  CFL 0950
      IF((NGF.EQ.0).AND.(NCUR.EQ.3)) GO TO 26                                   CFL 0960
   11 IF(IVERT.NE.1) GO TO 14                                                   CFL 0970
      WRITE(6,100)                                                              CFL 0980
  100 FORMAT('0',50X,'***SUMMARY ONE***',/,'0')                                 CFL 0990
      K=0                                                                       CFL 1000
      DO 31 I=1,8                                                               CFL 1010
      IF(ISUM1(I).NE.0) K=K+1                                                   CFL 1020
   31 CONTINUE                                                                  CFL 1030
      NUM1=K                                                                    CFL 1040
      IF(K.EQ.0) GO TO 14                                                       CFL 1050
      N=K*2                                                                     CFL 1060
      J=1                                                                       CFL 1070
      DO 33 I=1,NUM1                                                            CFL 1080
      IDEX=ISUM1(I)*2                                                           CFL 1090
      INAME(J)=NAMES(IDEX-1)                                                    CFL 1100
      INAME(J+1)=NAMES(IDEX)                                                    CFL 1110
      J=J+2                                                                     CFL 1120
   33 CONTINUE                                                                  CFL 1130
      WRITE(6,300)(INAME(I),I=1,N)                                              CFL 1140
  300 FORMAT('0',16A8)                                                          CFL 1150
      GO TO 4                                                                   CFL 1160
   26 ENDFILE 2                                                                 CFL 1170
      REWIND 2                                                                  CFL 1180
      NGF=NGRAF                                                                 CFL 1190
      J=1                                                                       CFL 1200
   27 READ(2,END=38)IQ,NCUR,NGRAF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(CFL 1210
     1L),L=1,IQ)                                                                CFL 1220
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      IF((NGF.EQ.NGRAF).AND.(NCUR.EQ.J)) GO TO 29                                  CFL 1230
      GO TO 27                                                                     CFL 1240
   29 LABEL=LAB(J+1)                                                               CFL 1250
C                                                                                  CFL 1260
      CALL DRAW(IC,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)            CFL 1270
C                                                                                  CFL 1280
      REWIND 2                                                                     CFL 1290
      J=J+1                                                                        CFL 1300
      IF(J.EQ.4) GO TO 38                                                          CFL 1310
      GO TO 27                                                                     CFL 1320
   38 NGF=NGF-1                                                                    CFL 1330
      IF(NGF.EQ.0) GO TO 11                                                        CFL 1340
      J=1                                                                          CFL 1350
      GO TO 27                                                                     CFL 1360
    4 READ(1,END=13)(PVQQ(I),I=1,26)                                               CFL 1370
      DO 35 I=1,NUM1                                                               CFL 1380
      J=ISUM1(I)                                                                   CFL 1390
   35 AFILE(I)=PVQQ(J)                                                             CFL 1400
      WRITE(6,400)(AFILE(I),I=1,NUM1)                                              CFL 1410
400   FORMAT('0',8(3X,F10.4,3X))                                                   ********
      GO TO 4                                                                      CFL 1430
   13 REWIND 1                                                                     CFL 1440
   14 IF(ILATRL.NE.1) GO TO 17                                                     CFL 1450
      WRITE(6,200)                                                                 CFL 1460
  200 FORMAT('0',50X,'***SUMMARY TWO***',/,'0')                                    CFL 1470
      K=0                                                                          CFL 1480
      DO 32 I=1,8                                                                  CFL 1490
      IF(ISUM2(I).NE.0) K=K+1                                                      CFL 1500
   32 CONTINUE                                                                     CFL 1510
      NUM2=K                                                                       CFL 1520
      IF(K.EQ.0) GO TO 16                                                          CFL 1530
      N=K*2                                                                        CFL 1540
      J=1                                                                          CFL 1550
      DO 34 I=1,NUM2                                                               CFL 1560
      IDEX=ISUM2(I)*2                                                              CFL 1570
      INAME(J)=NAMES(IDEX-1)                                                       CFL 1580
      INAME(J+1)=NAMES(IDEX)                                                       CFL 1590
      J=J+2                                                                        CFL 1600
   34 CONTINUE                                                                     CFL 1610
      WRITE(6,300)(INAME(I),I=1,N)                                                 CFL 1620
   23 READ(1,END=16)(PVQQ(I),I=1,26)                                               CFL 1630
      DO 36 I=1,NUM2                                                               CFL 1640
      J=ISUM2(I)                                                                   CFL 1650
   36 AFILE(I)=PVQQ(J)                                                             CFL 1660
      WRITE(6,400)(AFILE(I),I=1,NUM2)                                              CFL 1670
      GO TO 23                                                                     CFL 1680
   16 REWIND 1                                                                     CFL 1690
   17 RETURN                                                                       CFL 1700
```

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      END                                                                CFL 1710
C                                                                        DMV 0010
      SUBROUTINE DMINV (A,N,D)                                           DMV 0020
C                                                                        DMV 0030
      DIMENSION A(6,6),PIVOT(6)                                          DMV 0040
      DIMENSION IPVOT(6),INDEX(6,2)                                      DMV 0050
      EQUIVALENCE (IROW,JROW),(ICOL,JCOL)                                DMV 0060
C                                                                        DMV 0070
      D=1.0                                                              DMV 0080
      DO 17 J=1,N                                                        DMV 0090
      IPVOT(J)=0                                                         DMV 0100
   17 CONTINUE                                                           DMV 0110
      DO 135 I=1,N                                                       DMV 0120
      T=0.0                                                              DMV 0130
        DO 9 J=1,N                                                       DMV 0140
      IF(IPVOT(J)-1) 13,9,13                                             DMV 0150
   13 DO 23 K=1,N                                                        DMV 0160
      IF(IPVOT(K)-1) 43,23,81                                            DMV 0170
   43 IF (ABS(T)-ABS(A(J,K))) 83,23,23                                   DMV 0180
   83 IROW=J                                                             DMV 0190
      ICOL=K                                                             DMV 0200
      T=A(J,K)                                                           DMV 0210
   23 CONTINUE                                                           DMV 0220
    9 CONTINUE                                                           DMV 0230
      IPVOT(ICOL)=IPVOT(ICOL)+1                                          DMV 0240
      IF(IROW-ICOL) 73,109,73                                            DMV 0250
   73 D=-D                                                               DMV 0260
      DO 12 L=1,N                                                        DMV 0270
      T=A(IROW,L)                                                        DMV 0280
      A(IROW,L)=A(ICOL,L)                                                DMV 0290
      A(ICOL,L)=T                                                        DMV 0300
   12 CONTINUE                                                           DMV 0310
  109 INDEX(I,1)=IROW                                                    DMV 0320
      INDEX(I,2)=ICOL                                                    DMV 0330
      PIVOT(I)=A(ICOL,ICOL)                                              DMV 0340
      D=D*PIVOT(I)                                                       DMV 0350
      A(ICOL,ICOL)=1.0                                                   DMV 0360
      DO 205 L=1,N                                                       DMV 0370
      A(ICOL,L)=A(ICOL,L)/PIVOT(I)                                       DMV 0380
  205 CONTINUE                                                           DMV 0390
      DO 134 LI=1,N                                                      DMV 0400
      IF(LI-ICOL) 21,134,21                                              DMV 0410
   21 T=A(LI,ICOL)                                                       DMV 0420
      A(LI,ICOL)=0.0                                                     DMV 0430
      DO 89 L=1,N                                                        DMV 0440
      A(LI,L)=A(LI,L)-A(ICOL,L)*T                                        DMV 0450
   89 CONTINUE                                                           DMV 0460
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  134  CONTINUE                                                                DMV 0470
  135  CONTINUE                                                                DMV 0480
       DO 3 I=1,N                                                              DMV 0490
       L=N-I+1                                                                 DMV 0500
       IF(INDEX(L,1)-INDEX(L,2)) 19,3,19                                       DMV 0510
   19  JROW=INDEX(L,1)                                                         DMV 0520
       JCOL=INDEX(L,2)                                                         DMV 0530
       DO 549 K=1,N                                                            DMV 0540
       T=A(K,JROW)                                                             DMV 0550
       A(K,JROW)=A(K,JCOL)                                                     DMV 0560
       A(K,JCOL)=T                                                             DMV 0570
  549  CONTINUE                                                                DMV 0580
    3  CONTINUE                                                                DMV 0590
C                                                                              DMV 0600
   81  RETURN                                                                  DMV 0610
       END                                                                     DMV 0620

C                                                                              FAN 0010
       SUBROUTINE FAN                                                          FAN 0020
C                                                                              FAN 0030
       INTEGER ON                                                              FAN 0040
       COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                      FAN 0050
       COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,ENFAN 0060
      1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2FAN 0070
      25),TMEB(25),DELB(25),NB,TMES(25),DELS(25),NS                            FAN 0080
       COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  FAN 0090
       COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IFAN 0100
      1RUD,IPROP,IAEROD,IRHS                                                   FAN 0110
       COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVFAN 0120
      1GE(10)                                                                  FAN 0130
       COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAVFAN 0140
      1GS(10)                                                                  FAN 0150
       COMMON /VARBLE/ VAL(40)                                                 FAN 0160
       DIMENSION QB(1), QM(1), QS(1), PBOW(1), PM(1), PS(1), HP(8)             FAN 0170
       EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAFAN 0180
      1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAFAN 0190
      2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSIFAN 0200
      3, (VAL(24),PB)                                                          FAN 0210
       EQUIVALENCE (VAL(18),FANPWR)                                            FAN 0220
       EQUIVALENCE (VAL(35),PBARB),(VAL(36),PBARS)                             ********
       EQUIVALENCE (QBFAN(1),QB(1)), (QMFAN(1),QM(1)), (QSFAN(1),QS(1)),  FAN 0230
      1(PBFAN(1),PBOW(1)), (PMFAN(1),PM(1)), (PSFAN(1),PS(1))                  FAN 0240
       DATA HP/2.9,2.3,1.95,1.77,1.85,2.05,1.93,1.62/                          FAN 0250
C                                                                              FAN 0260
       ERAT = 8000/BRPM                                                        FAN 0270
       EMRAT = 8000/EMRPM                                                      FAN 0280
       SRAT = 8000/SRPM                                                        FAN 0290
       TL = VAL(1)                                                             FAN 0300
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```
      IF (NB.EQ.0.0) GO TO 1                                                FAN 0310
      DPBS = FG1(TL,NB,TMEB,DELB,ILB)                                       FAN 0320
      PBS = PB+DPBS                                                         FAN 0330
    1 IF (NS.EQ.0.0) GO TO 2                                                FAN 0340
      DPSS = FG1(TL,NS,TMES,DELS,ILS)                                       FAN 0350
      PSS = PB+DPSS                                                         FAN 0360
    2 CONTINUE                                                              FAN 0370
      PB1 = PBS-PINF                                                        FAN 0380
      PB2 = PB-PINF                                                         FAN 0390
      PB3 = PSS-PINF                                                        FAN 0400
      PBARB = PB1*BRAT**2                                                   FAN 0410
      PBARM = PB2*EMRAT**2                                                  FAN 0420
      PBARS = PB3*SRAT**2                                                   FAN 0430
      QBCW = ENBFAN*FG1(PBARB,NPTSB,PBOW,QB,IB)/BRAT                        FAN 0440
      QMAIN = ENMFAN*FG1(PBARM,NPTSM,PM,QM,IM)/EMRAT                        FAN 0450
      QSTN = ENSFAN*FG1(PBARS,NPTSS,PS,QS,IS)/SRAT                          FAN 0460
      QIN = QBOW+QMAIN+QSTN                                                 FAN 0470
      MB1 = (QBOW/ENBFAN+5.0)/5.0                                           FAN 0480
      MB2 = MB1+1                                                           FAN 0490
      MB3 = MB2+1                                                           FAN 0500
      BINC = ((QBOW/ENBFAN+5.0)-MB1*5.0)/5.0                                FAN 0510
      BFANHP = ((HP(MB3)-HP(MB2))*BINC+HP(MB2))*ENBFAN*(1./BRAT)**3.0       FAN 0520
      MS1 = (QSTN/ENSFAN+5.0)/5.0                                           FAN 0530
      MS2 = MS1+1                                                           FAN 0540
      MS3 = MS2+1                                                           FAN 0550
      SINC = ((QSTN/ENSFAN+5.0)-MS1*5.0)/5.0                                FAN 0560
      SFANHP = ((HP(MS3)-HP(MS2))*SINC+HP(MS2))*ENSFAN*(1./SRAT)**3.0       FAN 0570
      MM1 = (QMAIN/ENMFAN+5.0)/5.0                                          FAN 0580
      MM2 = MM1+1                                                           FAN 0590
      MM3 = MM2+1                                                           FAN 0600
      PINC = ((QMAIN/ENMFAN+5.0)-MM1*5.0)/5.0                               FAN 0610
      PFANHP = ((HP(MM3)-HP(MM2))*PINC+HP(MM2))*ENMFAN*(1./EMRAT)**3.0      FAN 0620
      RELPWR = PFANHP+BFANHP+SFANHP                                         FAN 0630
      FANPWR = (QBOW*PB1+QMAIN*PB2+QSTN*PB3)/550.                           FAN 0640
      FANEFF = FANPWR/RELPWR                                                FAN 0650
      IF (IRHS.NE.CN) RETURN                                                FAN 0660
      WRITE (6,3) QBOW,QMAIN,QSTN,PBARB,PBARM,PBARS,RELPWR,FANPWR,FANEFF    FAN 0670
C                                                                           FAN 0680
    3 FORMAT (//4H FAN/32H Q - BOW,MAIN,STERN (CU FT /SEC)3F12.1/28H DELFAN 0690
     1P - BOW,MAIN,STERN (PSF)3F11.2/60H ACTUAL FAN POWER REQUIRED(HP), FAN 0700
     2IDEAL FAN POWER, EFFICIENCY 3F12.4)                                   FAN 0710
C                                                                           FAN 0720
      RETURN                                                                FAN 0730
      END                                                                   FAN 0740

C                                                                           FG1 0010
      FUNCTION FG1(X,N,XT,YT,IX)                                            FG1 0020
C                                                                           FG1 0030
```

```
      DIMENSION XT(1),YT(1)                                                  FG1 0040
C                                                                            FG1 0050
      IF (IX.LT.1) IX=1                                                      FG1 0060
      IF (IX.GT.N-1) IX=N-1                                                  FG1 0070
      I=SIGN(1.0,X-XT(IX))                                                   FG1 0080
 10   IF (IX.LT.1 .OR. IX.GE.N) GO TO 30                                     FG1 0090
      IF (XT(IX).GT.X .OR. X.GT.XT(IX+1)) GO TO 20                           FG1 0100
      C=(X-XT(IX))/(XT(IX+1)-XT(IX))                                         FG1 0110
      GO TO 100                                                              FG1 0120
 20   IX=IX+I                                                                FG1 0130
      GO TO 10                                                               FG1 0140
 30   C=IX/N                                                                 FG1 0150
      IX=IX-I                                                                FG1 0160
 100  FG1=YT(IX)+C*(YT(IX+1)-YT(IX))                                         FG1 0170
      RETURN                                                                 FG1 0180
      END                                                                    FG1 0190

C                                                                            INCN0010
      SUBROUTINE INCON (TIME)                                                INCN0020
C                                                                            INCN0030
      REAL*8 TICRD                                                           INCN0040
      INTEGER ON                                                             INCN0050
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                     INCN0060
      COMMON/AXIS/NXYS(26)                                                   INCN0070
      COMMON /BMCO / IMP,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IYINCN0080
      COMMON /COLUMN/ IVERT,ILATRL                                           INCN0090
      COMMON /CONST/ PI,RAD,UO                                               INCN0100
      COMMON /CNTRL/CONTW,CONTQ,CONTTH,QMULT,LCUVER,ACONTZ,ACONTW,ZEQUILINCN0110
     1 ,THEQL,ACBASE                                                         INCN0120
      COMMON /CURVE/NCURV(10)                                                INCN0130
      COMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,          INCN0140
     ATIP(25),TIS(25)                                                        INCN0150
      COMMON /EQNCO/ NEQS,TCL(20),JQQ                                        INCN0160
      COMMON /FAIR/ RHOA,XLAERO                                              INCN0170
      COMMON /FANMAP/QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,        INCN0180
     1 ENSFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS                              INCN0190
     2 ,PBFAN(25),PMFAN(25),PSFAN(25),TMEB(25),DELB(25),NB,TMES(25),         INCN0200
     3DETS(25),NS                                                            INCN0210
      COMMON / FRCUDE / FN,FNCRIT                                            INCN0220
      COMMON/GBOW/ XBOW                                                      INCN0230
      COMMON /GEOM/    WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM          INCN0240
     1,DELS(4,10),XCP,ZCP                                                    INCN0250
      COMMON /GEOMSW/ XAVG(10),DS                                            INCN0260
      COMMON/GRAF/NGRAF,NDRW                                                 INCN0270
      COMMON /HEADG/TICRD(6)                                                 INCN0280
      COMMON /PWAVE/ FNCON,PWVCON                                            INCN0290
      COMMON/LEAKER/ALEAK,BLEAK,CFSS,CFBS                                    INCN0300
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,       INCN0310
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-                  AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO          INCN0320
 COMMON /MATRIX/ A(6,6)                                                 INCN0330
 COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA,IPITCH                          INCN0340
 COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT                                    INCN0350
 COMMON/PLVCOO/NVI,NVD,NLI,NLD                                          INCN0360
 COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                          INCN0370
 COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,       INCN0380
-IRLD,IPROP,IAEROD,IRHS                                                 INCN0390
 COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7       INCN0400
 COMMON /ROLL/ PHIMAX,TROLL                                             INCN0410
 COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,       INCN0420
ARCLB,RTC,RUDANG,TIR(25)                                                INCN0430
 COMMON /RISER/ AMPTC                                                   INCN0440
 COMMON/SOFTBS/XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVG      INCN0450
1B(10),CENCAB                                                           INCN0460
 COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS                INCN0470
1 ,ELMAXS,YAVGS(10)                                                     INCN0480
 COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWINCN0490
1,VAREA  ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ ,AVBMSW,DELX,VTC           INCN0500
 COMMON/SLOPE/WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                           INCN0510
 COMMON /STABLE/ S(4),ISTAB                                             INCN0520
 COMMON /STSLR/ CPHI,CPHID                                              INCN0530
 COMMON /SUM/ ISUM1(8),ISUM2(8)                                         INCN0540
 COMMON / VALOLD / YOLD(20)                                             INCN0550
 COMMON /VARBLE/ VAL(40)                                                INCN0560
 COMMON /WAVE/ ETA(4,11),AW(10),CMEGA(10),DVCLW,NWAVE,BETA,             INCN0570
1                FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                    INCN0580
2                ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR             INCN0590
 COMMON /WAVEF/WAVLEN(10),OMEGAE(10),WAVSLP(10),ENCPER(10)              INCN0600
 COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,       INCN0610
1          AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),            INCN0620
2          AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)                         INCN0630
3          ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),                      INCN0640
4          AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),            INCN0650
5          AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)                         INCN0660
6          ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)                       INCN0670
7          ,BB(36),XREF,RX                                             INCN0680
 DIMENSION ZZZ(14050)                                                   INCN0690
 EQUIVALENCE (ZZZ,NAL)                                                  INCN0700
 EQUIVALENCE                  (VAL(2),U),(VAL(3),V),(VAL(4),W),         INCN0710
1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),         INCN0720
2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),INCN0730
3(VAL(24),PB)                                                          INCN0740
 DIMENSION TEMP(7),XMO(10)                                              INCN0750
 DIMENSION TITLE(20)                                                    INCN0760
 DATA BEAM,BETAD,DELO,DELPI,DLRDO,DSO,ISYS,RMAXO,RCNO,RRATO,RREVO,      INCN0770
1 THETO,THSSI,TPRINO,UO,VXO,VZO,XBSI,XCPO,XLTOT,XPC,XRC,XSSI,YPO,      INCN0780
2 ZPC,ZRO,ZSSI/ 6*0.0,0,20*0.0/                                        INCN0790
```

```
C                                                                       INCN0800
C     INITIAL CONDITIONS WITH WATSLP                                    INCN0810
C                                                                       INCN0820
      DO 9 I=1,8                                                        INCN0830
      ISUM1(I)=0                                                        INCN0840
    9 ISUM2(I)=0                                                        INCN0850
      PINF=2116.                                                        INCN0860
      RHOINF=.002378                                                    INCN0870
      GAM=1.4                                                           INCN0880
      IOUT=600000                                                       INCN0890
      GO TO 10                                                          INCN0900
 2200 READ(5,3000) NGRAF,NDRW                                           INCN0910
 3000 FORMAT(2I2)                                                       INCN0920
      READ(5,3001) NXYS                                                 INCN0930
 3001 FORMAT(26I2)                                                      INCN0940
      READ(5,3002) TITRD                                                INCN0950
 3002 FORMAT(6A8)                                                       INCN0960
10    READ(5,99) ISYSL,IOPT,(TEMP(I),I=1,7)                             INCN0970
      IF( ISYSL .EQ. ISYS .AND. ISYSL.EQ. 13) GOTO 70                   INCN0980
      ISYS=ISYSL                                                        INCN0990
      IF((ISYS.LE.0).OR.(ISYS.GT.22)) GO TO 70                          INCN1000
      GOTO(100,200,300,400,500,600,700,800,900,1000,1100,1200,1300,     INCN1010
     1140C,1500,1600,1700,1800,1900,2000,2100,2200),ISYS                INCN1020
C                                                                       INCN1030
C     PROGRAM CONTROL PARAMETERS                                        INCN1040
C                                                                       INCN1050
100   CONTINUE                                                          INCN1060
      GOTO(101,102,103,104,105,106,107),IOPT                            INCN1070
 101  CONTINUE                                                          INCN1080
      STIME=TEMP(1)                                                     INCN1090
      FTIME=TEMP(2)                                                     INCN1100
      DELO=TEMP(3)                                                      INCN1110
      DELPNT=TEMP(4)                                                    INCN1120
      TPRINO=TEMP(5)                                                    INCN1130
      IF (TPRINO.LT.STIME+DELPNT)  TPRINO = STIME+DELPNT                INCN1140
      IF (DELO.GT.DELPNT) DELO=DELPNT                                   INCN1150
      IF (DELO.EQ.0.0) GO TO 140                                        INCN1160
      GOTO 10                                                           INCN1170
 2000 READ(5,3003) NCURV                                                INCN1180
 3003 FORMAT(10I1)                                                      INCN1190
      GO TO 10                                                          INCN1200
 2100 READ(5,2210) ISUM1                                                INCN1210
      READ(5,2210)ISUM2                                                 INCN1220
 2210 FORMAT(8I2)                                                       INCN1230
      GO TO 10                                                          INCN1240
102   READ (5,191) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,  INCN1250
     1 IPROP,IAERCD,IRHS                                                INCN1260
      GOTO 10                                                           INCN1270
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```
103   READ (5,175) NEQS,JQQ,(TOL(J),J=1,NEQS)                    INCN1270
      GCTO 10                                                     INCN1280
 104  READ(5,191) IVERT,ILATRL,NVD,NVI,NLD,NLI                    INCN1290
      GC TO 10                                                    INCN1300
 105  CCNTINUE                                                    INCN1310
      I3DOF=TEMP(1)                                               INCN1320
      ISRGE=TEMP(2)                                               INCN1330
      ITRIM=TEMP(3)                                               INCN1340
      IDIA=TEMP(4)                                                INCN1350
      IPITCH=TEMP(5)                                              ********
      GC TO 10                                                    INCN1360
 106  CCNTINUE                                                    INCN1370
      PRCMO1=TEMP(1)                                              INCN1380
      PRCMO2=TEMP(2)                                              INCN1390
      PRCMO3=TEMP(3)                                              INCN1400
      PRCMO4=TEMP(4)                                              INCN1410
      PRCMO5=TEMP(5)                                              INCN1420
      PRCMO6=TEMP(6)                                              INCN1430
      PRCMO7=TEMP(7)                                              INCN1440
      GC TO 10                                                    INCN1450
107   CCNTINUE                                                    INCN1451
      IF(TEMP(1).NE.0.)PINF=TEMP(1)                               INCN1452
      IF(TEMP(2).NE.0.)RHOINF=TEMP(2)                             INCN1453
      IF(TEMP(3).NE.0.)GAM=TEMP(3)                                INCN1454
      READ(5,2041) IQUIT                                          INCN1455
 2041 FCRMAT(I10)                                                 INCN1456
      GCTO 10                                                     INCN1457
 140  WRITE(6,195)                                                INCN1460
      STCP                                                        INCN1470
C                                                                 INCN1480
C     MASS DISTRIBUTION                                           INCN1490
C                                                                 INCN1500
 200  G=32.17                                                     INCN1510
      RHC=1.99                                                    INCN1520
      HRHC=RHC/2.                                                 INCN1530
      GC TO (210,220,230), IOPT                                   INCN1540
 210  IMM = 0                                                     INCN1550
      WEIGHT = TEMP(1)                                            INCN1560
      AM = WEIGHT/G                                               INCN1570
      XS = TEMP(2)                                                INCN1580
      ZS = TEMP(3)                                                INCN1590
      AIXX = TEMP(4)                                              INCN1600
      AIYY = TEMP(5)                                              INCN1610
      AIZZ = TEMP(6)                                              INCN1620
      AIXZ = TEMP(7)                                              INCN1630
C                                                                 INCN1640
C     INERTIA MATRIX OPERATIONS                                   INCN1650
C                                                                 INCN1660
```

```
  212 DO 211 I=1,6                                                        INCN1670
      DO 211 N=1,6                                                        INCN1680
  211 A(I,N) = 0.0                                                        INCN1690
      DO 213 N=1,3                                                        INCN1700
  213 A(N,N)=AM                                                           INCN1710
      A(4,4)=AIXX                                                         INCN1720
      A(5,5)=AIYY                                                         INCN1730
      A(6,6)=AIZZ                                                         INCN1740
      A(4,6)=-AIXZ                                                        INCN1750
      A(6,4)=-AIXZ                                                        INCN1760
      AIMAX=AMAX1(AM,AIXX,AIYY,AIZZ,ABS(AIXZ))                            INCN1770
      DO 214 I=1,6                                                        INCN1780
      DO 214 J=1,6                                                        INCN1790
  214 A(I,J)=A(I,J)/AIMAX                                                 INCN1800
C                                                                         INCN1810
      CALL DMINV (A,6,D)                                                  INCN1820
C                                                                         INCN1830
      DO 215 I=1,6                                                        INCN1840
      DO 215 J=1,6                                                        INCN1850
  215 A(I,J)=A(I,J)/AIMAX                                                 INCN1860
      IF (D.NE.0.0) GO TO 10                                              INCN1870
      WRITE (6,216)                                                       INCN1880
      STOP                                                                INCN1890
C                                                                         INCN1900
CC    READ WEIGHT DISTRIBUTION - ASSUME TRANSVERSE (PORT/STBD) SYMMETRY   INCN1910
CC       X INPUT DIST. FWD. OF (SIDEWALL) TRANSOM                         INCN1920
CC       Y INPUT DIST. TO STARBOARD                                       INCN1930
CC       Z INPUT DIST. UP FROM KEEL-LINE                                  INCN1940
C                                                                         INCN1950
  220 I = 1                                                               INCN1960
  222 READ (5,192) AMI(I),XI(I),YI(I),ZI(I)                               INCN1970
      IF (AMI(I).LT.0.0)  GO TO 224                                       INCN1980
      I = I+1                                                             INCN1990
      IF ( I.GT.201 )  GO TO 70                                           INCN2000
      GO TO 222                                                           INCN2010
  224 NMASS = I-1                                                         INCN2020
      SUM = 0.0                                                           INCN2030
      SUX = 0.0                                                           INCN2040
      SUZ = 0.0                                                           INCN2050
      DO 225 I=1,NMASS                                                    INCN2060
      AMI(I) = AMI(I)/G                                                   INCN2070
      SUM = SUM+AMI(I)                                                    INCN2080
      SUX = SUX+AMI(I)*XI(I)                                              INCN2090
  225 SUZ = SUZ+AMI(I)*ZI(I)                                              INCN2100
      AM = SUM*2.0                                                        INCN2110
      WEIGHT = AM*G                                                       INCN2120
      ZS  = SUZ/SUM                                                       INCN2130
      XS  = SUX/SUM                                                       INCN2140
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      SUM = 0.0                                                          INCN2150
      SUX = 0.0                                                          INCN2160
      SUY = 0.0                                                          INCN2170
      SUZ = 0.0                                                          INCN2180
      DO 226 I=1,NMASS                                                   INCN2190
      XI(I) = XI(I)-XS                                                   INCN2200
      ZI(I) = -ZI(I)+ZS                                                  INCN2210
      AMK = AMI(I)*2.0                                                   INCN2220
      SUX = SUX+AMK*XI(I)*XI(I)                                          INCN2230
      SUY = SUY+AMK*YI(I)*YI(I)                                          INCN2240
      SUZ = SUZ+AMK*ZI(I)*ZI(I)                                          INCN2250
  226 SUM = SUM+AMK*XI(I)*ZI(I)                                          INCN2260
      AIXX = SUY+SUZ                                                     INCN2270
      AIYY = SUX+SUZ                                                     INCN2280
      AIZZ = SUX+SUY                                                     INCN2290
      AIXZ = SUM                                                         INCN2300
      GO TO 212                                                          INCN2310
  230 GO TO 10                                                           INCN2320
C                                                                        INCN2330
C     XX AND YY TABLES                                                   INCN2340
C                                                                        INCN2350
300   CONTINUE                                                           INCN2360
      NSTA(1) = TEMP(1)                                                  INCN2370
      NSTA(2) = TEMP(2)                                                  INCN2380
      NSTA(3) = TEMP(3)                                                  INCN2390
      NSTA(4) = TEMP(4)                                                  INCN2400
      XLTOT=TEMP(5)                                                      INCN2410
      GOTO 10                                                            INCN2420
C                                                                        INCN2430
C     SIDEWALL (INCLUDING APPENDAGES)                                    INCN2440
C                                                                        INCN2450
400   CONTINUE                                                           INCN2460
      GOTO (401,402),IOPT                                                INCN2470
401   YSW=TEMP(1)                                                        INCN2480
      XLSW=TEMP(2)                                                       INCN2490
      CFSW=TEMP(3)                                                       INCN2500
      CDSW=TEMP(4)                                                       INCN2510
      AVBMSW=TEMP(5)                                                     INCN2520
      READ (10) ZZZ                                                      INCN2530
      REWIND 10                                                          INCN2540
      GOTO 10                                                            INCN2550
C                                                                        INCN2560
C    BLOCK 4 OPTION 2 REMOVED.       NO APENDAGES                        INCN2570
C                                                                        INCN2580
  402 CONTINUE                                                           INCN2590
      GOTO 10                                                            INCN2600
C                                                                        INCN2610
C     STERNSEAL                                                          INCN2620
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C                                                                       INCN2630
500   CCNTINUE                                                          INCN2640
      XSSI=TEMP(1)                                                      INCN2650
      ZSSI=TEMP(2)                                                      INCN2660
      ALEAK=TEMP(3)                                                     INCN2670
      CFSS=TEMP(4)                                                      INCN2680
      ELMAXS = TEMP(5)                                                  INCN2690
      DFSS=TEMP(6)                                                      INCN2700
      XLF=TEMP(7)                                                       INCN2710
      ARGA = ELMAXS/XLF                                                 INCN2720
      CCSTH = ARGA                                                      INCN2730
      THSSI = ARCCS(ARGA)                                               INCN2740
      SINTH = SIN(THSSI)                                                INCN2750
      GC TO 10                                                          INCN2760
C                                                                       INCN2770
C     BCWSEAL                                                           INCN2780
C                                                                       INCN2790
 600  GC TO(610,620),IOPT                                               INCN2800
 610  CCNTINUE                                                          INCN2810
      XBSI=TEMP(1)                                                      INCN2820
      CFBS=TEMP(2)                                                      INCN2830
      DFBS=TEMP(3)                                                      INCN2840
      ZBSI=TEMP(4)                                                      INCN2850
      ELMAXB = TEMP(5)                                                  INCN2860
      XBF=TEMP(6)                                                       INCN2870
      BLEAK=TEMP(7)                                                     INCN2880
      GCTO 10                                                           INCN2890
 620  CENCAB=TEMP(1)                                                    INCN2900
      GC TO 10                                                          INCN2910
C                                                                       INCN2920
C     PLENUM                                                            INCN2930
C                                                                       INCN2940
700   CCNTINUE                                                          INCN2950
      GC TO (705,710),IOPT                                              INCN2960
 705  CCNTINUE                                                          INCN2970
      XLBW=TEMP(1)                                                      INCN2980
      XBBW=TEMP(2)                                                      INCN2990
      XPWV=TEMP(3)                                                      INCN3000
      WIDTH=TEMP(4)                                                     INCN3010
      XL=TEMP(5)                                                        INCN3020
      XCPC=TEMP(6)                                                      INCN3030
      BUBHGT=TEMP(7)                                                    INCN3040
      XLXPWV=XLBW-XPWV                                                  INCN3050
      PWVHT=(XPWV*XPWV-XLXPWV*XLXPWV)*.5/XL                             INCN3060
      XPWVXS=XPWV-XS                                                    INCN3070
      ABW=XBBW*XLBW                                                     INCN3080
      AB=WIDTH*XL                                                       INCN3090
      VCLNOM=(ABW+AB)*BUBHGT/2.                                         INCN3100
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      GCTO 10                                                          INCN3110
 71C  CCNTINUE                                                         INCN3120
      FNCRIT=TEMP(1)                                                   INCN3130
      GC TO 10                                                         INCN3140
C                                                                      INCN3150
C     FRCPULSION                                                       INCN3160
C                                                                      INCN3170
800   CCNTINUE                                                         INCN3180
      GC TO (805,810),IOPT                                             INCN3190
 805  CCNTINUE                                                         INCN3200
      XPC=TEMP(1)                                                      INCN3210
      YPC=TEMP(2)                                                      INCN3220
      ZPC=TEMP(3)                                                      INCN3230
      GC TO 10                                                         INCN3240
C                                                                      INCN3250
C BLCCK 8 OPTION 2 REMOVED. ENGINE OUT INPUT IN BLOCK 16               INCN3260
C                                                                      INCN3270
  81C CCNTINUE                                                         INCN3280
      GCTO 10                                                          INCN3290
C                                                                      INCN3300
C     RUDDER                                                           INCN3310
C                                                                      INCN3320
900   CCNTINUE                                                         INCN3330
      GC TO (905,910,915),IOPT                                         INCN3340
  905 XRC = TEMP(1)                                                    INCN3350
      YR=TEMP(2)                                                       INCN3360
      ZRC = TEMP(3)                                                    INCN3370
      RSPAN=TEMP(4)                                                    INCN3380
      RASPR=TEMP(5)                                                    INCN3390
      RAREA=TEMP(6)                                                    INCN3400
      RCLB=2.*PI*RASPR/(RASPR+3.)                                      INCN3410
      RTC=TEMP(7)                                                      INCN3420
      GC TO 10                                                         INCN3430
C                                                                      INCN3440
C     91C NOT USED                                                     INCN3450
C                                                                      INCN3460
  910 CCNTINUE                                                         INCN3470
      GC TO 10                                                         INCN3480
 915  CCNTINUE                                                         INCN3490
      GCTO 10                                                          INCN3500
C                                                                      INCN3510
C     AERODYNAMICS                                                     INCN3520
C                                                                      INCN3530
1000  CCNTINUE                                                         INCN3540
      XLAERC=TEMP(1)                                                   INCN3550
      BEAM=TEMP(2)                                                     INCN3560
      RHOA=.5*RHOINF*XLAERO*BEAM                                       INCN3570
      GCTO 10                                                          INCN3580
```

```
C                                                                       INCN3590
C     WAVES                                                             INCN3600
C                                                                       INCN3610
1100  CONTINUE                                                          INCN3620
      IWAVSW=IOPT                                                       INCN3630
      IF(IWAVSW.GT.4) GO TO 70                                          INCN3640
      NWAVE=TEMP(1)                                                     INCN3650
      IF(NWAVE .EQ. 0) GOTO 10                                          INCN3660
      IF(NWAVE .GT. 10) GOTO 70                                         INCN3670
      BETAD=TEMP(2)                                                     INCN3680
      BETA=BETAD/RAD                                                    INCN3690
      COSBET=COS(BETA)                                                  INCN3700
      SINBET=SIN(BETA)                                                  INCN3710
      TC = 1.0                                                          INCN3720
      GO TO (1104,1106,1108,1108),IWAVSW                                INCN3730
1104  DO 1105 I=1,NWAVE                                                 INCN3740
1105  READ(5,1190) OMEGA(I),AW(I)                                       INCN3750
      GOTO 10                                                           INCN3760
1106  DO 1107 I=1,NWAVE                                                 INCN3770
1107  READ (5,1190) WAVLEN(I) ,AW(I)                                    INCN3780
      GOTO 10                                                           INCN3790
 1108 SHTWV=TEMP(3)                                                     INCN3800
      G1G=32.17                                                         INCN3810
      G2=G1G*G1G                                                        INCN3820
      G4=G2*G2                                                          INCN3830
      GOTO(10,10,1110,1111),IWAVSW                                      INCN3840
 1110 CONTINUE                                                          INCN3850
      PERL=TEMP(4)                                                      INCN3860
      PERH=TEMP(5)                                                      INCN3870
      WWN=(2.0*3.141592)*(1.0/PERH)                                     INCN3880
      WWX=(2.0*3.141592)*(1.0/PERL)                                     INCN3890
      GO TO 1112                                                        INCN3900
 1111 CONTINUE                                                          INCN3910
      WWN = TEMP(4)                                                     INCN3920
      WWX = TEMP(5)                                                     INCN3930
 1112 CONTINUE                                                          INCN3940
      UUU=SQRT(SHTWV/0.0185)*1.6878                                     INCN3950
      UU4=UUU**4.                                                       INCN3960
      CCC=(WWX/WWN)**(1./NWAVE)                                         INCN3970
      WWPO =WWN                                                         INCN3980
      DO 1113 I = 1,NWAVE                                               INCN3990
      WWPN = WWPO*CCC                                                   INCN4000
      WW =(WWPN+WWPO)/2                                                 INCN4010
      DDW = WWPN-WWPO                                                   INCN4020
      WWPO  = WWPN                                                      INCN4030
      WW4= WW**4.0                                                      INCN4040
      WW5 = WW**5.0                                                     INCN4050
      SS = 0.0081*G2/(EXP(0.74*G4/(WW4*UU4))*WW5)                       INCN4060
```

```
      OMEGA(I) =Wk                                                          INCN4070
      Ak(I) = SQRT(2.*SS*DDW)                                               INCN4080
 1113 CONTINUE                                                              INCN4090
      GO TO 10                                                              INCN4100
C                                                                           INCN4110
C     INITIAL CONDITIONS                                                    INCN4120
C                                                                           INCN4130
1200  CONTINUE                                                              INCN4140
      UO = TEMP(1)                                                          INCN4150
      THETO = TEMP(2)                                                       INCN4160
      OSO = TEMP(3)                                                         INCN4170
      DELPI=TEMP(4)                                                         INCN4180
      OPHI = TEMP(5)                                                        INCN4190
      GO TO 10                                                              INCN4200
1300  CONTINUE                                                              INCN4210
C                                                                           INCN4220
C     INPUT COMPLETED. 1) PRINT ALL INPUT                                   INCN4230
C                                                                           INCN4240
      WRITE(6,2004) TITLE                                                   INCN4250
      WRITE(6,2030) PINF,RHOINF,GAM                                         INCN4251
      WRITE (6,2001) STIME,FTIME,DELO,TPRINO,DELPAT                         INCN4260
      WRITE (6,2002) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,    INCN4270
     1 IPROP,IAERCD,IRHS                                                    INCN4280
      WRITE(6,2021) I3DOF,ISRGE,ITRIM,ICIA                                  INCN4290
      WRITE (6,2029) PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7       INCN4300
      WRITE (6,2003) NEQS, (TOL(J),J=1,NEQS)                                INCN4310
      WRITE (6,219) WEIGHT,XS,ZS,AIXX,AIYY,AIZZ,AIXZ                        INCN4320
      WRITE(6,217)A,AIMAX                                                   INCN4330
      WRITE (6,2018) NSTA                                                   INCN4340
      WRITE (6,490) YSW,XLSW,CFSW,CDSW,VANGLE,VSPAN,VCHORD,VXO,VY,VZO,      INCN4350
     1 AVBMSW,VTC                                                           INCN4360
      WRITE (6,491) NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB         INCN4370
      IF (IMM.GT.0)  WRITE(6,1549)   (XMO(J),J=1,IMNX)                      INCN4380
      WRITE (6,1519) IMM,IMNX,IMNY,IBMFIL,BTIME,IMT                         INCN4390
      IF (IMM.GT.0)  WRITE(6,1559) (YMI(J),J=1,IMNY)                        INCN4400
      WRITE (6,2010) XLBW,XBBW                                              INCN4410
      WRITE (6,2011) XL,WIDTH,XCPO,VOLNOM,BUBHGT                            INCN4420
      WRITE (6,2020) DELPI                                                  INCN4430
      WRITE(6,2009) FNCRIT,XLTOT                                            INCN4440
      WRITE (6,2028) ENBFAN,BRPM,ENMFAN,EMRPM,ENSFAN,SRPM                   INCN4450
      WRITE (6,2013) XRO,YR,ZRO,RONO,RMAXO,RRATO,RREVO,DLRDO                INCN4460
     1   ,RSPAN,RASPR,RAREA,RCLB,RTC                                        INCN4470
      WRITE (6,2012)        XPO,YPO,ZPO                                     INCN4480
      WRITE (6,2027) XLAERO,BEAM                                            INCN4490
      WRITE (6,2026) XBSI,CFBS,DPBS,ELMAXB                                  INCN4500
      WRITE (6,2025) XSSI,ZSSI,ALEAK,CFSS,ELMAXS,DPSS,XLF                   INCN4510
      WRITE (6,2017) UO,THETO,DSO                                           INCN4520
C                                                                           INCN4530
```

```
C                    AND 2) INITIALIZE VARIABLES FOR CALCS.                  INCN4540
C                                                                            INCN4550
      DO 1302 I=1,40                                                         INCN4560
 1302 VAL(I) = 0.0                                                           INCN4570
      U = UO*1.6889                                                          INCN4580
      XSS=-(XS-XSSI)                                                         INCN4590
      ZSS=ZS-ZSSI                                                            INCN4600
      THETA = THETO/RAD                                                      INCN4610
      PHI = DPHI/RAD                                                         INCN4620
      THEQL=THETA                                                            INCN4630
      DS = DSC/12.                                                           INCN4640
      Z=-ZS+DS                                                               INCN4650
      ZEQUIL=Z                                                               INCN4660
      PHIMAX=0.                                                              INCN4670
      TRCLL=0.                                                               INCN4680
      IRDS=0                                                                 INCN4690
      TL=0.0                                                                 INCN4700
C                                                                            INCN4710
C     WAVE PARAMETERS TABLE                                                  INCN4720
C                                                                            INCN4730
      IF(NWAVE .EQ.0) GOTO 1321                                              INCN4740
      AMPTC=1.30287                                                          INCN4750
      GOTO(1310,1315),IWAVSW                                                 INCN4760
1310  DO 1311 I=1,NWAVE                                                      INCN4770
1311  WAVLEN(I)=2.*PI*G/(OMEGA(I)*OMEGA(I))                                  INCN4780
      GOTO 1317                                                              INCN4790
1315  DO 1316 I=1,NWAVE                                                      INCN4800
1316  OMEGA(I)=SQRT(2.*PI*G/WAVLEN(I))                                       INCN4810
1317  CONTINUE                                                               INCN4820
C                                                                            INCN4830
C     CALCULATE INITIAL FREQUENCIES OF ENCOUNTER                             INCN4840
C                                                                            INCN4850
      DO 1318 I=1,NWAVE                                                      INCN4860
      WAVSLP(I) = 360.0*AW(I)/WAVLEN(I)                                      INCN4870
      OMEGAE(I) =2.*PI*(SQRT(G*WAVLEN(I)/(2.*PI))-U*COSBET)/WAVLEN(I)        INCN4880
      ENCPER(I) = 2.0*PI/OMEGAE(I)                                           INCN4890
1318  CONTINUE                                                               INCN4900
      WRITE (6,1191) NWAVE,BETAD,(OMEGA(I),OMEGAE(I),WAVLEN(I),AW(I),        INCN4910
     1                WAVSLP(I),ENCPER(I),I=1,NWAVE)                        INCN4920
      GOTO 1322                                                              INCN4930
 1321 WRITE (6,1192)                                                         INCN4940
1322  CONTINUE                                                               INCN4950
      DO 1303 I=1,4                                                          INCN4960
      DO 1303 N=1,11                                                         INCN4970
 1303 ETA(I,N) = 0.0                                                         INCN4980
      CVCLW = 0.0                                                            INCN4990
      FXWAV = 0.0                                                            INCN5000
      FYWAV = 0.0                                                            INCN5010
```

```
      FZWAV = 0.0                                                       INCN5020
      FKWAV = 0.0                                                       INCN5030
      FMWAV = 0.0                                                       INCN5040
      FNWAV = 0.0                                                       INCN5050
      ZBAR=Z                                                            INCN5060
      PHIBAR=PHI                                                        INCN5070
      THEBAR=THETA                                                      INCN5080
      TIME=STIME                                                        INCN5090
      DELT = DELO                                                       INCN5100
      TPRINT=TPRINO-DELPNT                                              INCN5110
      PWVCCN=4.*WEIGHT/(RHO*G*XLBW)                                     INCN5120
      FNCCN=SQRT(XLBW*G)                                                INCN5130
      VX=VXO-XS                                                         INCN5140
      VZ = ZS-VZO                                                       INCN5150
      XP=XPO-XS                                                         INCN5160
      XR = XRC-XS                                                       INCN5170
      YP=YPO                                                            INCN5180
      ZP=ZS-ZPO                                                         INCN5190
      ZR = ZS-ZRO                                                       INCN5200
      IF (IMM.EQ. 0) GO TO 1305                                         INCN5210
      DO 1304 J=1,IMNX                                                  INCN5220
 1304 XMI(J) = XMO(J) - XS                                              INCN5230
 1305 CONTINUE                                                          INCN5240
      XCP = XCPO-XS                                                     INCN5250
      ZCP = ZS-BUBHGT                                                   INCN5260
      XBS=XBSI-XS                                                       INCN5270
      N=NSTA(3)                                                         INCN5280
      ZBS=ZS-ZBSI                                                       INCN5290
      DO 1364 J=1,N                                                     INCN5300
      DELYBS=XBBW/(N-1)                                                 INCN5310
       XX(3,J)=XBS-XSSI                                                 INCN5320
      YY(3,J)=-0.5*XBBW+(J-1)*DELYBS                                    INCN5330
 1364 CONTINUE                                                          INCN5340
      N=N-1                                                             INCN5350
      DO 1367 J=1,N                                                     INCN5360
      YAVGB(J)=(YY(3,J+1)+YY(3,J))/2.                                   INCN5370
 1367  CONTINUE                                                         INCN5380
      N=NSTA(4)                                                         INCN5390
      DELYSS=XBBW/(N-1)                                                 INCN5400
      DO 1365 J=1,N                                                     INCN5410
      XX(4,J)=-XS                                                       INCN5420
      YY(4,J)=-.5*XBBW+(J-1)*DELYSS                                     INCN5430
 1365 CONTINUE                                                          INCN5440
      N=N-1                                                             INCN5450
      DO 1368 J=1,N                                                     INCN5460
      YAVGS(J)=(YY(4,J+1)+YY(4,J))/2.                                   INCN5470
 1368 CONTINUE                                                          INCN5480
      XBCW=XLTOT-XS                                                     INCN5490
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      N=NSTA(1)                                                          INCN5500
      DELX=XBSI/(N-1)                                                    INCN5510
      DO 1309 J=1,2                                                      INCN5520
      DO 1309 I=1,N                                                      INCN5530
      XX(J,I)=(I-1)*DELX-XS                                              INCN5540
 1309 YY(J,I)= YSW*(2*J-3)                                               INCN5550
      WRITE(6,1366) ((XX(J,N),N=1,11),(YY(J,N),N=1,11),J=1,4)            INCN5560
 1366 FORMAT (//17H XX AND YY ARRAYS /14H PORT SIDEWALL /2(11F10.2/),    INCN5570
     1 15H STBD. SIDEWALL /2(11F10.2/),9H BOW SEAL /2(11F10.2/),         INCN5580
     2 11H STERN SEAL /2(11F10.2/))                                      INCN5590
      N=NSTA(1)-1                                                        INCN5600
      DO 1308 I=1,N                                                      INCN5610
 1308 XAVG(I)=DELX*(2*I-1)/2.-XS                                         INCN5620
C                                                                        INCN5630
      CALL WAVES(TIME)                                                   INCN5640
C                                                                        INCN5650
C     INITIALIZE BUBBLE PRESSURE, ABSOLUTE (PSF)                         INCN5660
C                                                                        INCN5670
      PE=PINF+DELPI                                                      INCN5680
      PEBAR=DELPI                                                        INCN5690
      PEAR=DELPI                                                         INCN5700
      PSS=PB+DPSS                                                        INCN5710
      PES=PB+CPBS                                                        INCN5720
      AE=ABW-(ABW-AB)*(ZS+Z/BUBHGT)                                      INCN5730
      CF=.37/((U/FNCON)**1.5655981)                                      INCN5740
      WATSLP=PBBAR*CF*PWVCON/WEIGHT                                      INCN5750
      IF (IDIA.EQ.1) GO TO 6                                             INCN5760
      VCL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVCLW                                INCN5770
     1+.5*WATSLP*XL*AB                                                   INCN5780
      GO TO 7                                                            INCN5790
 6    VCL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVCLW+PBAR*.3175333                  INCN5800
 7    CONTINUE                                                           INCN5810
      BMASS=(PB/PINF)**(1./GAM)*VOL*RHOINF                               INCN5820
      WRITE (6,2023)                                                     INCN5830
      RETURN                                                             INCN5840
C                                                                        INCN5850
C     RUN TERMINATOR                                                     INCN5860
C                                                                        INCN5870
 1400 WRITE(6,98)                                                        INCN5880
      STOP                                                               INCN5890
C                                                                        INCN5900
C     BENDING MOMENT                                                     INCN5910
C                                                                        INCN5920
 1500 GO TO (1510,1520,1530,1540), IOPT                                  INCN5930
 1510 IMM = TEMP(1)                                                      INCN5940
      IF (IMM.GT.3)  GO TO 70                                            INCN5950
      IMNX = TEMP(2)                                                     INCN5960
      IF (IMNX.GT.10)  GO TO 70                                          INCN5970
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      IMNY = TEMP(3)                                                    INCN5980
      IF (IMNY.GT.7)  GO TO 70                                          INCN5990
      IBMFIL = TEMP(4)                                                  INCN6000
      BTIME = TEMP(5)                                                   INCN6010
      IF (IMM.EQ.3)  IMT = TEMP(6)                                      INCN6020
      GO TO 10                                                          INCN6030
 1520 DO 1521 J=1,7                                                     INCN6040
 1521 XMO(J) = TEMP(J)                                                  INCN6050
      IF (IMNX.LE.7)  GO TO 10                                          INCN6060
      READ 1522, (XMO(J),J=8,IMNX)                                      INCN6070
      GO TO 10                                                          INCN6080
 1530 DO 1531 J=1,IMNY                                                  INCN6090
 1531 YMI(J) = TEMP(J)                                                  INCN6100
      GO TO 10                                                          INCN6110
 1540 CONTINUE                                                          INCN6120
      GO TO 10                                                          INCN6130
 1600 CONTINUE                                                          INCN6140
      GO TO(1605,1610,1615),IOPT                                        INCN6150
 1605 CONTINUE                                                          INCN6160
C                                                                       INCN6170
C   VALUES INPUT FOR STBD SCREW                                         INCN6180
C                                                                       INCN6190
      THST1=TEMP(1)                                                     INCN6200
      NPS=TEMP(2)                                                       INCN6210
      STHS=TEMP(3)                                                      INCN6220
      IF(NPS.EQ.0.0) GO TO 1609                                         INCN6230
      READ(5,1950)(TIS(J),J=1,NPS)                                      INCN6240
      READ(5,1950)(THSTS(J),J=1,NPS)                                    INCN6250
      GO TO 10                                                          INCN6260
 1609 THSTS(1)=THST1                                                    INCN6270
 1610 CONTINUE                                                          INCN6280
C                                                                       INCN6290
C   VALUES INPUT FOR PORT SCREW                                         INCN6300
C                                                                       INCN6310
      THST2=TEMP(1)                                                     INCN6320
      NPP=TEMP(2)                                                       INCN6330
      STHP=TEMP(3)                                                      INCN6340
      IF(NPP.EQ.0.0) GO TO 1614                                         INCN6350
      READ(5,1950)(TIP(J),J=1,NPP)                                      INCN6360
      READ(5,1950)(THSTP(J),J=1,NPP)                                    INCN6370
      GO TO 10                                                          INCN6380
 1614 THSTP(1)=THST2                                                    INCN6390
 1615 CONTINUE                                                          INCN6400
C                                                                       INCN6410
C   VALUES INPUT FOR RUDDER                                             INCN6420
C                                                                       INCN6430
      DELR=TEMP(1)                                                      INCN6440
      NPR=TEMP(2)                                                       INCN6450
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      IF(NPR.EQ.0.0) GO TO 1616                                          INCN6460
      READ(5,1950)(TIR(J),J=1,NPR)                                       INCN6470
      READ(5,1950)(DELRUD(J),J=1,NPR)                                    INCN6480
      GO TO 10                                                           INCN6490
 1616 DELRUD(1)=DELR                                                     INCN6500
      GO TO 10                                                           INCN6510
 1700 GO TO (1705,1710),IOPT                                             INCN6520
 1705 NB=TEMP(1)                                                         INCN6530
      READ(5,1950)(TMEB(I),I=1,NB)                                       INCN6540
      READ(5,1950)(DELB(I),I=1,NB)                                       INCN6550
      GO TO 10                                                           INCN6560
 1710 NS=TEMP(1)                                                         INCN6570
      READ(5,1950)(TMES(I),I=1,NS)                                       INCN6580
      READ(5,1950)(DETS(I),I=1,NS)                                       INCN6590
      GOTO 10                                                            INCN6600
C                                                                        INCN6610
CC    TITLE CARD (ALL 80 COLUMNS )                                       INCN6620
C                                                                        INCN6630
 1800 READ  (5,2022)  TITLC                                              INCN6640
      GO TO 10                                                           INCN6650
C                                                                        INCN6660
CC    FAN MAPS                                                           INCN6670
C                                                                        INCN6680
1900  CONTINUE                                                           INCN6690
      GO TO (1905,1910,1915),IOPT                                        INCN6700
1905  CONTINUE                                                           INCN6710
      ENBFAN=TEMP(1)                                                     INCN6720
      BRPM=TEMP(2)                                                       INCN6730
      NPTSB=TEMP(3)                                                      INCN6740
      READIN=TEMP(4)                                                     INCN6750
      IF (READIN .EQ. 0.0) GO TO 10                                      INCN6760
      READ (5,1950) (PBFAN(J),J=1,NPTSB)                                 INCN6770
      READ (5,1950) (QBFAN(J),J=1,NPTSB)                                 INCN6780
      GO TO 10                                                           INCN6790
1910  CONTINUE                                                           INCN6800
      ENMFAN=TEMP(1)                                                     INCN6810
      EMRPM=TEMP(2)                                                      INCN6820
      NPTSM=TEMP(3)                                                      INCN6830
      READIN=TEMP(4)                                                     INCN6840
      IF (READIN .EQ. 0.0) GO TO 10                                      INCN6850
      READ (5,1950) (PMFAN(J),J=1,NPTSM)                                 INCN6860
      READ (5,1950) (QMFAN(J),J=1,NPTSM)                                 INCN6870
      GO TO 10                                                           INCN6880
1915  CONTINUE                                                           INCN6890
      ENSFAN=TEMP(1)                                                     INCN6900
      SRPM=TEMP(2)                                                       INCN6910
      NPTSS=TEMP(3)                                                      INCN6920
      READIN=TEMP(4)                                                     INCN6930
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      IF (READIN .EQ. 0.0) GO TO 10                                     INCN6940
      READ (5,1950) (PSFAN(J),J=1,NPTSS)                                INCN6950
      READ (5,1950) (QSFAN(J),J=1,NPTSS)                                INCN6960
      GO TO 10                                                          INCN6970
1950  FORMAT(8F10.0)                                                    INCN6980
C                                                                       INCN6990
C     ERROR IN INPUT                                                    INCN7000
C                                                                       INCN7010
   70 CONTINUE                                                          INCN7020
      WRITE (6,79) ISYS                                                 INCN7030
      STOP                                                              INCN7040
C                                                                       INCN7050
  79  FORMAT(34H INPUT ERROR - - - STOP - -  ISYS= ,I3)                 INCN7060
  98  FORMAT(1H1,20(/),50X,19H COMPLETED ALL RUNS )                     INCN7070
99    FORMAT(I3,I2,7F10.0)                                              INCN7080
 191  FORMAT (16I5)                                                     INCN7090
 192  FORMAT (5F10.0)                                                   INCN7100
 195  FORMAT(///10X,65HERROR IN INPUT --- DELT AND/OR DELPNT EQUALS ZERO INCN7110
     1 --- JOB ABORTED )                                                INCN7120
 175  FORMAT (2I2/(8F10.0))                                             INCN7130
 216  FORMAT(///10X,82HERROR IN INPUT --- INPUT INERTIA ELEMENTS LEAD TO INCN7140
     1 ZERO DETERMINANT --- JOB ABORTED )                               INCN7150
 217  FORMAT(22H INERTIA MATRIX, AIMAX  6E15.4/(22X,6E15.4))            INCN7160
 219  FORMAT(30H WEIGHT, C.G., INERTIA MOMENTS 7F12.3)                   INCN7170
 305  FORMAT ( 11F7.0 )                                                 INCN7180
 490  FORMAT(15H SIDEWALL INPUT 12(F8.3,1X))                            INCN7190
 491  FORMAT(26H SIDEWALL TABLE PARAMETERS 4(I4,F7.3,F7.3))             INCN7200
1190  FORMAT(2F10.0)                                                    INCN7210
 1191 FORMAT(/12HONO OF WAVES I2,10H BETA(DEG)F5.0/15H OMEGA(RAD/SEC) , INCN7220
     15X,16H OMEGAE(RAD/SEC) 5X,16H WAVE LENGTH(FT) 5X,14H AMPLITUDE(FT)INCN7230
     - 5X,16HMAX  SLOPE (DEG)5X,13HPERIOD,E(SEC)/(F8.4,12X,F8.4,4F20.3))INCN7240
 1192 FORMAT(/11HOCALM WATER)                                           INCN7250
 1519 FORMAT(32HOMOMENT CALC. CONTROL PARAMETERS 4I5, F8.3, I5 )        INCN7260
 1522 FORMAT ( 5X,7F10.0)                                               INCN7270
 1549 FORMAT(22H MOMENT CALCS. AT X OF 11F10.3)                         INCN7280
 1559 FORMAT(22H MOMENT CALCS. AT Y OF 11F10.3)                         INCN7290
 2004 FORMAT(33H1SES MOTIONS AND LOADS PROGRAM - 20A4,/)                INCN7300
 2001 FORMAT(23H START AND FINISH TIMES 2F10.2/                         INCN7310
     -22H INITIAL TIME INTERVAL F12.4/                                  INCN7320
     -18H START PRINTING AT F8.2,17H IN INCREMENTS OF F8.2)             INCN7330
 2002 FORMAT(24H INTERMEDIATE PRINT TAGS 16I5)                          INCN7340
 2003 FORMAT(39H NO. OF STATE EQUATIONS, AND TOLERANCESI5/(10X,10E12.2))INCN7350
 2009 FORMAT(23HOCRITICAL FROUDE NUMBER F15.4,5X,19H TOTAL CRAFT LENGTH INCN7360
     1        F15.4)                                                    INCN7370
 2010 FORMAT(34HOPLENUM, LENGTH AND WIDTH AT WATER 2F12.4)              INCN7380
 2011 FORMAT(34H PLENUM, LENGTH AND WIDTH AT HULL  2F12.4/              INCN7390
     -       35H PLENUM, CENTER OF PRESSURE AT HULL F12.4/              INCN7400
     -23H PLENUM, NOMINAL VOLUME F12.1,10X, 6HHEIGHT F12.4)             INCN7410
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 2012 FORMAT(/33H PROPULSION, X, Y, Z COORDINATES  3F12.4/)                INCN7420
 2013 FORMAT(/28HORUDDER, X, Y, Z COORDINATES  3F12.4/                     INCN7430
     -        41H RUDDER, ON, MAX, RATE, REVERSE, INITIAL  5F12.4/        INCN7440
     -        33H RUDDER,SPAN,ASPECT,AREA,CLB,T/C  5F12.4)                INCN7450
 2017 FORMAT(/39HOINITIAL CONDITIONS, VELOCITY (KNOTS) = F7.2, 5X,         INCN7460
     -        13HPITCH (DEG) = F8.3,5X,12HDRAFT (IN) = F8.2)              INCN7470
 2018 FORMAT( 49H NUMBER OF STATIONS, SIDEWALLS (P+S), SEALS (B+S) ,4I5)INCN7480
 2020 FORMAT( 38H PLENUM, INITIAL PRESSURE, GAGE (PSF)  F8.2)             INCN7490
 2021 FORMAT(79H PROGRAM OPTION SWITCH SETTINGS (LATERAL PLANE,CONSTANT INCN7500
     -SPEED,TRIM,MEMBRANE)     7I5)                                       INCN7510
 2022 FORMAT (20A4 )                                                      INCN7520
 2023 FORMAT ( 1H1 )                                                      INCN7530
 2025 FORMAT( 16H STERNSEAL INPUT  7F12.4 )                               INCN7540
 2026 FORMAT( 16H BOWSEAL INPUT    7F12.4 )                              INCN7550
 2027 FORMAT( 19HOAERODYNAMICS INPUT  7F12.4)                             INCN7560
 2028 FORMAT( 33HOFANS, NO. + RPM, BOW,MAIN,STERN  3(F10.C,F10.1))        INCN7570
 2029 FORMAT(32H PROGRAM MODIFICATION SETTINGS        7(F12.4,1X))        INCN7580
2030  FORMAT(' PINF =',F8.2,5X,'RHOINF =',F10.7,5X,'GAM = ',F8.2/)        INCN7581
      END                                                                 INCN7590

C                                                                         INT 0010
      SUBROUTINE INTGRL (TIME)                                            INT 0020
C                                                                         INT 0030
      INTEGER ON                                                          INT 0040
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,INT,XMI(10),YMI(7),IX,IYINT 0050
      COMMON /EQNCO/ NEQS,TOL(20),JQQ                                     INT 0060
      COMMON /KSWTCH/ ITHRST                                              INT 0070
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,    INT 0080
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO        INT 0090
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                       INT 0100
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7    INT 0110
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,    INT 0120
     -IROD,IPROP,IAEROD,IRHS                                              INT 0130
      COMMON /STABLE/ S(4),ISTAB                                          INT 0140
      COMMON/STEP/STEP2                                                   INT 0150
      COMMON / VALOLD / YOLD(20)                                          INT 0160
      COMMON /VARBLE/ VAL(40)                                             INT 0170
      EQUIVALENCE (VAL(1),X),(VAL(2),Y(1))                                INT 0180
      DIMENSION Y(20),ERROR(20)                                           INT 0190
      REAL K1(20),K2(20),K3(20),K4(20),K5(20)                             INT 0200
      DATA IPASS/0/                                                       INT 0210
C                                                                         INT 0220
      STEP2=1.0                                                           INT 0230
      PB=VAL(24)                                                          INT 0240
      BMASS=Y(10)                                                         INT 0250
    1 IF((TIME+DELT).LE.TPRINT) GO TO 12                                  INT 0260
      DEL=DELT                                                            INT 0270
      DELT=TPRINT-TIME                                                    INT 0280
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      IPASS=1                                                          INT 0290
   12 X=TIME                                                           INT 0300
      DO 2 J=1,NEQS                                                    INT 0310
      Y(J)=YOLD(J)                                                     INT 0320
    2 CONTINUE                                                         INT 0330
      ITHRST=1                                                         INT 0340
C                                                                      INT 0350
      CALL RHS(K1)                                                     INT 0360
C                                                                      INT 0370
      ITHRST=2                                                         INT 0380
      IMT = 0                                                          INT 0390
      IF (IACCEL.NE. ON) GO TO 14                                      INT 0400
      ACCLAT = (K1(2)+Y(1)*Y(6))/G                                     INT 0410
      WRITE  (6,101)  ACCLAT , DELT                                    INT 0420
   14 CN=2                                                             INT 0430
   15 H=DELT/3.                                                        INT 0440
      X=TIME+H                                                         INT 0450
      DO 3 J=1,NEQS                                                    INT 0460
    3 Y(J)=YOLD(J)+H*K1(J)                                             INT 0470
C                                                                      INT 0480
      CALL RHS(K2)                                                     INT 0490
C                                                                      INT 0500
      DO 4 J=1,NEQS                                                    INT 0510
    4 Y(J)=YOLD(J)+.5*H*(K1(J)+K2(J))                                  INT 0520
C                                                                      INT 0530
      CALL RHS(K3)                                                     INT 0540
C                                                                      INT 0550
      X=TIME+.5*DELT                                                   INT 0560
      DO 5 J=1,NEQS                                                    INT 0570
    5 Y(J)=YOLD(J)+.375*H*(K1(J)+3.*K3(J))                             INT 0580
C                                                                      INT 0590
      CALL RHS(K4)                                                     INT 0600
C                                                                      INT 0610
      X=TIME+DELT                                                      INT 0620
      DO 6 J=1,NEQS                                                    INT 0630
    6 Y(J)=YOLD(J)+.5*H*(3.*K1(J)-9.*K3(J)+12.*K4(J))                  INT 0640
C                                                                      INT 0650
      CALL RHS(K5)                                                     INT 0660
C                                                                      INT 0670
      IF (JOB.EQ. 1 ) GO TO 7                                          INT 0680
      DO 7 J=1,NEQS                                                    INT 0690
      ERROR(J)=(K1(J)-4.5*K3(J)+4.*K4(J)-.5*K5(J))*H/5.0               INT 0700
      IF(ABS(ERROR(J)).GT.TOL(J)) GO TO 11                             INT 0710
    7 CONTINUE                                                         INT 0720
      DO 105 J=1,NEQS                                                  INT 0730
      Y(J)=YOLD(J)+.5*H*(K1(J)+4.*K4(J)+K5(J))                         INT 0740
  105 YOLD(J)=Y(J)                                                     INT 0750
      TIME=TIME+DELT                                                   INT 0760
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      IF (IPASS.EQ.1) GO TO 8                                                  INT 0770
      IF (JCQ.EQ. 1 ) GO TO 10                                                 INT 0780
      DC 75 J=1,NEQS                                                           INT 0790
      IF(ABS(ERROR(J)).GT.TOL(J)/16.) GO TO 9                                  INT 0800
   75 CCNTINUE                                                                 INT 0810
      DELT=2.*DELT                                                             INT 0820
      IF (DELT.GT.DELPNT) DELT=DELPNT                                          INT 0830
C                                                                              INT 0840
   10 RETURN                                                                   INT 0850
C                                                                              INT 0860
    9 STEP2=DELT                                                               INT 0870
      GC TO 10                                                                 INT 0880
    8 CELT=DEL                                                                 INT 0890
      IPASS=0                                                                  INT 0900
      GC TO 10                                                                 INT 0910
   11 CELT=DELT/2.                                                             INT 0920
      IF (DELT.LT. 1.E-6 )  GO TO 25                                           INT 0930
      IF(JQQ.EQ.2) GO TO 26                                                    INT 0940
                        WRITE (6,666) TIME,DELT,J,ERROR(J),TOL(J)              INT 0950
   27 IPASS=0                                                                  INT 0960
      GC TO 15                                                                 INT 0970
   26 STEP1=DELT*2.0                                                           INT 0980
      IF(STEP1.LT.STEP2)STEP2=STEP1                                            INT 0990
      GC TO 27                                                                 INT 1000
   25 WRITE ( 6,150 )                                                          INT 1010
      WRITE (6,100) TIME,DELT,(K1(J),J=1,NEQS),VAL                             INT 1020
      CALL COLFIL                                                              INT 1021
      STCP                                                                     INT 1030
C                                                                              INT 1040
  100 FCRMAT(/10X,23HINTGRL TIME,DELT,K1,VAL /2E15.4/2(5E15.4/),5(8E15.4INT 1050
     1/))                                                                      INT 1060
  101 FCRMAT(1HO,9X,33HTCTAL LATERAL ACCELERATION (G) =   F12.4,               INT 1070
     112X,5HDT =  E15.4)                                                       INT 1080
  150 FORMAT(1H1,10X,44HDELTA TIME LESS THAN 1.0E-6  -  -  JOB STOPS )         INT 1090
  666 FCRMAT(/10X,5HINT-J 2E30.5,I5,2E20.5)                                    INT 1100
      END                                                                      INT 1110

C                                                                              PROP0010
      SLBROUTINE PROP                                                          PROP0020
C                                                                              PROP0030
      INTEGER ON                                                               PROP0040
      CCMMON /CONST/ PI,RAD,UO                                                 PROP0050
      CCMMON /FPROP/ FX,FY,FZ,FK,FM,FN                                         PROP0060
      CCMMCN/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,            PROP0070
     ATIP(25),TIS(25)                                                          PROP0080
      CCMMCN /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,         PROP0090
     -IRUD,IPROP,IAEROD,IRHS                                                   PROP0100
      CCMMCN /PROMOD/ PROMO1,PROMO2,PROMO3,PROMC4,PROMO5,PROMO6,PROMO7         PROP0110
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      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,   PROP0120
     ARCLB,RTC,RUDANG,TIR(25)                                            PROP0130
      COMMON /VARBLE/ VAL(40)                                            PROP0140
      EQUIVALENCE (VAL(1),TIME),(VAL(2),U),(VAL(3),V),(VAL(4),W),        PROP0150
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),      PROP0160
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),PROP0170
     3(VAL(24),PB)                                                       PROP0180
      DIMENSION THS(1),THP(1),TS(1),TP(1),RUD(1),TR(1)                   PROP0190
      EQUIVALENCE (THSTS(1),THS(1)),(THSTP(1),THP(1)),(TIS(1),TS(1)),(TIPROP0200
     AP(1),TP(1)),(TIR(1),TR(1)),(DELRUD(1),RUD(1))                      PROP0210
C                                                                        PROP0220
      FX = 0.0                                                           PROP0230
      FY = 0.0                                                           PROP0240
      FZ = 0.0                                                           PROP0250
      FK = 0.0                                                           PROP0260
      FM = 0.0                                                           PROP0270
      FN = 0.0                                                           PROP0280
      TL=TIME                                                            PROP0290
      IF(NPR.EQ.0.0) GO TO 5                                             PROP0300
      RUDANG=FG1(TL,NPR,TR,RUD,IR)                                       PROP0310
      RUDANG=RUDANG/RAD                                                  PROP0320
C                                                                        PROP0330
CC    CALCULATE THRUSTS AND MOMENTS INDIVIDUALLY                         PROP0340
C                                                                        PROP0350
      GO TO 6                                                            PROP0360
    5 RUDANG=DELRUD(1)                                                   PROP0370
      RUDANG=RUDANG/RAD                                                  PROP0380
    6 CD=COS(RUDANG)                                                     PROP0390
      SD=SIN(RUDANG)                                                     PROP0400
      IF(NPS.EQ.0.0) GO TO 2                                             PROP0410
      THSS=FG1(TL,NPS,TS,THS,IS)                                         PROP0420
      GO TO 4                                                            PROP0430
    2 THSS=THSTS(1)                                                      PROP0440
    4 IF(NPP.EQ.0.0) GO TO 3                                             PROP0450
      THSP=FG1(TL,NPP,TP,THP,IP)                                         PROP0460
      GO TO 1                                                            PROP0470
    3 THSP=THSTP(1)                                                      PROP0480
    1 STHSTS=STHS*THSS                                                   PROP0490
      STHSTP=STHP*THSP                                                   PROP0500
      FXS=THSS*CD+STHSTS*SD                                              PROP0510
      FXP=THSP*CD-STHSTP*SD                                              PROP0520
      FYS=-STHSTS*CD+THSS*SD                                             PROP0530
      FYP=STHSTP*CD+SD*THSP                                              PROP0540
      FZS=-THSS*THETA*CD-STHSTS*CD*PHI                                   PROP0550
      FZP=-THSP*THETA*CD+STHSTP*CD*PHI                                   PROP0560
      FX=FXP+FXS                                                         PROP0570
      FY=FYP+FYS                                                         PROP0580
      FZ=FZP+FZS                                                         PROP0590
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      FKP=-FZP*YP-FYP*ZP                                                PROP0600
      FKS=FZS*YP-FYS*ZP                                                 PROP0610
      FK=FKS+FKP                                                        PROP0620
      FMS=FZS*(-XP)+FXS*ZP                                              PROP0630
      FMP=FZP*(-XP)+FXP*ZP                                              PROP0640
      FM=FMS+FMP                                                        PROP0650
      FNS=-FXS*YP-FYS*(-XP)                                             PROP0660
      FNP=FXP*YP-FYP*(-XP)                                              PROP0670
      FN=FNS+FNP                                                        PROP0680
      IF (IPROP.NE.ON) RETURN                                           PROP0690
                       WRITE(6,123)                                     PROP0700
     1FX,FY,FZ,FK,FM,FN                                                 PROP0710
  123 FORMAT(/10X,22HPROP FX,FY,FZ,FK,FM,FN  /6E15.4)                   PROP0720
      RETURN                                                            PROP0730
      END                                                               PROP0740

      SUBROUTINE RHS(VALUE)                                             RHS 0020
C                                                                       RHS 0030
      INTEGER ON                                                        RHS 0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                RHS 0050
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IYRHS 0060
      COMMON /COLUMN/ IVERT,ILATRL                                      RHS 0070
      COMMON /CONST/ PI,RAD,UO                                          RHS 0080
      COMMON /CNTRL/CONTW,CONTQ,CONTTH,QMULT,LCUVER,ACONTZ,ACONTW,ZEQUILRHS 0090
     1 ,THEQL,ACBASE                                                    RHS 0100
      COMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,     RHS 0110
     ATIP(25),TIS(25)                                                   RHS 0120
      COMMON /FANMAP/QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,   RHS 0130
     1 ENSFAN,BRPM,MRPM,SRPM,NPTSB,NPTSM,NPTSS                          RHS 0140
     2 ,PBFAN(25),PMFAN(25),PSFAN(25),TMEB(25),DELB(25),NB,TMES(25),    RHS 0150
     3DETS(25),NS                                                       RHS 0160
      COMMON /FAERO/ FXAED,FYAED,FZAED,FKAED,FMAED,FNAED                RHS 0170
      COMMON /FORBS/FXBS,FYBS,FZBS,FKBS,FMBS,FNBS,QLBS                  RHS 0180
      COMMON /FORSS/FXSS,FYSS,FZSS,FKSS,FMSS,FNSS,QLSS,FMS              RHS 0190
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP                            RHS 0200
      COMMON / FRCUDE / FN,FNCRIT                                       RHS 0210
      COMMON /FRUD/ FXRUD,FYRUD,FZRUD,FKRUD,FMRUD,FNRUD                 RHS 0220
      COMMON/GBOW/ XBOW                                                 RHS 0230
      COMMON /GEOM/    WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VCLNOM     RHS 0240
     1,DELS(4,10),XCP,ZCP                                               RHS 0250
      COMMON /GEOMBS/DETABX(11),DETABT(11),ARM1B(10),ARM2B(10)          RHS 0260
     1 ,DFBS(10),TSKIB(10)                                              RHS 0270
      COMMON /GEOMSS/DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10) RHS 0280
     1 ,ARM2S(10)                                                       RHS 0290
      COMMON /KSWTCH/ ITHRST                                            RHS 0300
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,  RHS 0310
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO       RHS 0320
      COMMON /MATRIX/ A(6,6)                                            RHS 0330
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      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),   RHS 0340
     1               FNH(2),VFY(2),VFZ(2),FXV                            RHS 0350
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)           RHS 0360
      COMMON /OPTION/I3DOF,ISRGE,ITRIM,IDIA,IPITCH                       RHS 0370
      COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT                                RHS 0380
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                      RHS 0390
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,   RHS 0400
     -IRUD,IPROP,IAEROD,IRHS                                             RHS 0410
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7   RHS 0420
      COMMON /PWAVE/ FNCON,PWVCON                                        RHS 0430
      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,   RHS 0440
     ARCLB,RTC,RUDANG,TIR(25)                                            RHS 0450
      COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWRHS 0460
     1,VAREA  ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC      RHS 0470
      COMMON/SLOPE/WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                       RHS 0480
      COMMON/SOFTBS/XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVG  RHS 0490
     1B(10),CENCAB                                                       RHS 0500
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS            RHS 0510
     1 ,ELMAXS,YAVGS(10)                                                 RHS 0520
      COMMON / VALOLD / YOLD(20)                                         RHS 0530
      COMMON /VARBLE/ VAL(40)                                            RHS 0540
      COMMON /WAVE/ ETA(4,11),AW(10),CMEGA(10),DVOLW,NWAVE,BETA,         RHS 0550
     1               FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                 RHS 0560
     2               ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR          RHS 0570
      EQUIVALENCE (VAL(1),TIME),(VAL(2),U),(VAL(3),V),(VAL(4),W),        RHS 0580
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),      RHS 0590
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),RHS 0600
     3(VAL(24),PB)                                                       RHS 0610
      EQUIVALENCE (VAL(18),FANPWR)                                       RHS 0620
      EQUIVALENCE (VAL(35),PBARB),(VAL(36),PBARS)
      DATA NOTIN /0/                                                     RHS 0630
      DIMENSION ACCEL(3),ANGACL(3)                                       RHS 0640
      DIMENSION GF(6),VALUE(20)                                          RHS 0650
C     WRITE (6,9876) (VAL(J),J=1,11)
C9876 FORMAT ('0',11E12.5)
C                                                                        RHS 0660
      DO 5 J=1,20                                                        RHS 0670
    5 VALUE(J)=0.0                                                       RHS 0680
C                                                                        RHS 0690
C     CALCULATION OF BUBBLE WAVE MAKING DRAG                             RHS 0700
C                                                                        RHS 0710
      AB=ABW-(ABW-(XL*WIDTH))*(ZS+Z)/BUBHGT                              RHS 0720
      IF (IDIA.EQ.1) GO TO 6                                             RHS 0730
      FN=U/FNCON                                                         RHS 0740
      CF=.37/(FN**1.5655981)                                             RHS 0750
      FXPWAV=-PWVCON*PBBAR*CF                                            RHS 0760
      WATSLP=-FXPWAV/WEIGHT                                              RHS 0770
      VOL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW                                RHS 0780
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     1+.5*WATSLP*XL*AB                                                                                    RHS 0790
      GC TO 7                                                                                             RHS 0800
C                                                                                                         RHS 0810
C    MEMERANE STUDY                                                                                       RHS 0820
C                                                                                                         RHS 0830
 6     PBAR=VAL(24)-PINF                                                                                  RHS 0840
       VCL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVCLW+PBAR*.3175333                                                  RHS 0850
 7     CCNTINUE                                                                                           RHS 0860
       PB=PINF*(BMASS/(VOL*RHOINF))**GAM                                                                  RHS 0870
       PBS=PB+DPBS                                                                                        RHS 0880
       PSS=PB+DPSS                                                                                        RHS 0890
       PBAR=PB-PINF                                                                                       RHS 0900
       ABPB=PBAR*AB                                                                                       RHS 0910
                                                                                                          RHS 0920
C      CALCULATION OF BUBBLE WAVE MAKING DRAG                                                             RHS 0930
C                                                                                                         RHS 0940
       FLCW=SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)                                                       RHS 0950
       QLSW=CFSW*ALSW*FLCW                                                                                RHS 0960
C                                                                                                         RHS 0970
       CALL BOWSL                                                                                         RHS 0980
       CALL STNSL                                                                                         RHS 0990
C                                                                                                         RHS 1000
       GF(1)=FXBS+FXSS+FXSW+FXRUD+FXP+FXWAV+FXAED                    +FXPWAV                              RHS 1010
       IF (ITHRST.NE.ITRIM) GO TO 11                                                                      RHS 1020
       THSTS(1)=THSTS(1)-GF(1)/2.                                                                         RHS 1030
       THSTP(1)=THSTP(1)-GF(1)/2.                                                                         RHS 1040
       THST=THSTS(1)+THSTP(1)                                                                             RHS 1050
       GF(1) = 0.0                                                                                        RHS 1060
   11  CCNTINUE                                                                                           RHS 1070
       GF(2)=-R*U*AM+FYBS+FYSS+FYSW+FYRUD+FYP+FYWAV+FYAED                                                 RHS 1080
       GF(3)=WEIGHT-ABPB          +FZBS+FZSS+FZSW+FZRUD+FZP+FZWAV+FZAED                                   RHS 1090
       GF(4)=FKBS+FKSS+FKSW+FKRUD+FKP+FKWAV+FKAED +ABPB*PHI*(-Z)                                          RHS 1100
C                                                                                                         RHS 1110
C      CALCULATION OF EFFECTIVE CENTER OF PRESSURE                                                        RHS 1120
C                                                                                                         RHS 1130
       XCPU=XCP+0.001975*(U/1.6889-30.0)**2-0.974                                                         RHS 1140
       XCPC=SHXYAX(XCPU,ZCP,THETA,PI)                                                                     RHS 1150
       FMBUB=ABPB*XCPC                                                                                    RHS 1160
       GF(5)=FMBS+FMSS+FMSW+FMRUD+FMP+FMWAV+FMAED+FMBUB+FXPWAV*ZS                                         RHS 1170
       FWAVZ=FXPWAV*ZS                                                                                    RHS 1180
       GF(6)=FNBS+FNSS+FNSW+FNRUD+FNP+FNWAV+FNAED                                                         RHS 1190
       IF(I3DOF.NE.1.OR.I3DOF.NE.2.OR.I3DOF.NE.3) GO TO 100
       IF(I3DOF.NE.3) GF(3)=0.0
       GF(5)=0.0                                                                                          RHS 1220
 100   CCNTINUE                                                                                           RHS 1230
       DO 1 I=1,6                                                                                         RHS 1240
       VALUE(I)=0.0                                                                                       RHS 1250
       DO 1 J=1,6                                                                                         RHS 1260
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      VALUE(I)=VALUE(I)+A(I,J)*GF(J)                                    RHS 1270
    1 CONTINUE                                                          RHS 1280
      IF(IPITCH.EQ.1) VALUE(4)=0.0
      VALUE(7)=P                                                        RHS 1290
      VALUE(8)=Q                                                        RHS 1300
      IF(IPITCH.EQ.1) VALUE(8)=0.0
      VALUE(9)=W                                                        RHS 1310
      IF (I3DOF .EQ. 1 ) GO TO 325                                      RHS 1320
C                                                                       RHS 1330
C     BUBBLE PRESSURE EQUATION                                          RHS 1340
C                                                                       RHS 1350
      QCLT=QLBS+QLSS+QLSW                                               RHS 1360
C                                                                       RHS 1370
      CALL FAN                                                          RHS 1380
C                                                                       RHS 1390
      QCNTRL=0.0                                                        RHS 1400
      VALUE(10)=RHOINF*(QIN-QOUT-QCNTRL)                                RHS 1410
      GO TO 236                                                         RHS 1420
  325 CONTINUE                                                          RHS 1430
      VALUE(10)=0.0                                                     RHS 1440
  236 CONTINUE                                                          RHS 1450
C                                                                       RHS 1460
C     WRITE DATA FILE FOR MOMENT AND SHEAR CALCS., IF REQUIRED          RHS 1470
C                                                                       RHS 1480
      IF ( IMT.NE.1 )  GO TO 111                                        RHS 1490
      NBS = NSTA(3)-1                                                   RHS 1500
      NSS = NSTA(4)-1                                                   RHS 1510
      NSSL = NSS/2+1                                                    RHS 1520
                  WRITE (IBMFIL)  (VAL(I),I=1,24),ZBAR,PHIBAR,THEBAR,RHS 1530
     -            FXW,FYW,FZW,FKW,FMW,FNW, (VALUE(I),I=1,10),          RHS 1540
     -            DF,DSWAV,FXH,FYH,FZH,FMH,FNH,VFY,VFZ,FXV ,           RHS 1550
     -            FXRUD,FYRUD,FXP,FYP,FZP,  FZSS,FKSS,FMSS,FXBS,FZBS,RHS 1560
     -            FXAED,FYAED,FZAED,FMAED,FNAED,FXPWAV,FXSS,FKBS,FMBSRHS 1570
     X  ,FNBS,FNSS ,(TSKIS(I),DFSS(I),I=NSSL,NSS)                       RHS 1580
     Y              ,(TSKIB(I),DFBS(I),ARM1B(I),ARM2B(I),I=1,NBS)      RHS 1590
  111 CONTINUE                                                          RHS 1600
C                                                                       RHS 1610
C     CONSTANT LONGITUDINAL VELOCITY ( U )                              RHS 1620
C                                                                       RHS 1630
      IF (ISRGE .EQ.1) VALUE(1)=0.0                                     RHS 1640
C     WRITE (6,9875) (VALUE(IQX),IQX=1,10)
C9875 FORMAT (13X,10E12.5)
      IF (ON.NE.1) RETURN                                               RHS 1650
      DO 2 I=1,3                                                        RHS 1660
      ACCEL(I)=VALUE(I)/G                                               RHS 1670
      ANGACL(I)=VALUE(I+3)*RAD                                          RHS 1680
    2 CONTINUE                                                          RHS 1690
      BCWACC=ACCEL(3)-XBOW*VALUE(5)/G                                   RHS 1700
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      STNACC=ACCEL(3)+XS*VALUE(5)/G                                          RHS 1710
      IF(IVERT.NE.ON) GO TO 10                                               RHS 1720
      ZD=Z+ZS                                                                RHS 1730
      VELP=VEL                                                               RHS 1740
      THETAR=THETA*RAD                                                       RHS 1750
      QDEG=Q*RAD                                                             RHS 1760
   10 IF(ILATRL.NE.ON) GO TO 15                                              RHS 1770
      DEPSI=PSI*RAD                                                          RHS 1780
      PDEG=P*RAD                                                             RHS 1790
      RDEG=R*RAD                                                             RHS 1800
      BETAS=-V/U*RAD                                                         RHS 1810
      ACCLAT=(VALUE(2)+U*R)/G                                                RHS 1820
      DPHI=PHI*RAD                                                           RHS 1830
      DRFT=12.0*ZD                                                           RHS 1840
      VEL=U/1.6889                                                           RHS 1850
      DELRS=RUDANG*RAD                                                       RHS 1860
      IF(R.EQ.0.0) GO TO 115                                                 RHS 1870
      TRADUS=U/R                                                             RHS 1880
      GO TO 20                                                               RHS 1890
  115 TRADUS=1.E8                                                            RHS 1900
   20  WRITE(1)TIME,BMASS,DRFT,THETAR,PBAR,BOWACC,ACCEL(3),FANPWR,PBARB,PRHS 1910
     1BARS,VAL(16),VEL,PDEG,VELP,X,Y,QIN,QOUT,GF(1),FXPWAV,THSTS(1),THSTRHS 1920
     2P(1),QDEG,FZSS,FXSS,DPHI                                               RHS 1930
   15  IF (IRHS .NE. ON) RETURN                                              RHS 1940
       WRITE(6,77) FMBS,FMSS,FMSW,FMRUD,FMP,FMWAV,FMAED,FMBUB,FWAVZ          RHS 1950
      WRITE(6,401)FXPWAV                                                     RHS 1960
      WRITE(6,200) PBAR,FANPWR,QIN,QLBS,QLSW,QLSS                            RHS 1970
      WRITE(6,215) AB,VOL                                                    RHS 1980
                   WRITE(6,213) VALUE,VAL                                    RHS 1990
      WRITE(6,150) GF,ACCEL,ANGACL                                           RHS 2000
      WRITE(6,175)BOWACC,STNACC                                              RHS 2010
C                                                                            RHS 2020
   77 FORMAT('0',6X,5HFMBS=,E16.6,2X,5HFMSS=,E16.6,2X,5HFMSW=,               RHS 2030
     AE16.6,/,'0',6X,6HFMRUD=,E16.6,2X,4HFMP=,E16.6,2X,6HFMWAV=,E16.6,       RHS 2040
     B/,'0',6X,6HFMAED=,E16.6,2X,6HFMBUB=,E16.6,2X,6HFWAVZ=,E16.6)           RHS 2050
  401 FORMAT('0',6X,7HFXPWAV=,E16.6)                                         RHS 2060
  200 FORMAT(//10X,3HRHS                                                     RHS 2070
     120H GAGE PRESS. (PSF) = F7.2,5X,21HFAN POWER REQD (HP) =  F8.2,        RHS 2080
     25X,27HFAN FLOW RATE (CU FT/SEC) =  F9.2,                               RHS 2090
     3//31H LEAKAGE FLOW RATES (CU FT/SEC)  //11H BOW SEAL = F9.2,           RHS 2100
     411H SIDEWALL = F9.2,13H STERN SEAL = F9.2)                             RHS 2110
  215 FORMAT(/13H PLENUM AREA= F9.2,10X,14HPLENUM VOLUME= F10.2)             RHS 2120
  213 FORMAT(//12H VALUE ARRAY 2(/10E13.4)/10H VAL ARRAY 4(/10E13.4))        RHS 2130
  150 FORMAT(/10X,24HTOTAL FORCES AND MOMENTS 6E12.4/10X,24HACCELERATIONRHS 2140
     -S G,DEG/SEC2 6E12.4)                                                   RHS 2150
  175 FORMAT(/10X,16HBOW ACCEL. (G) = E12.4,21H   STERN ACCEL. (G) = E12RHS 2160
     -.4)                                                                    RHS 2170
C                                                                            RHS 2180
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      RETURN                                                                RHS 2190
      END                                                                   RHS 2200
C                                                                           RUD 0010
      SUBROUTINE RUDDER                                                     RUD 0020
C                                                                           RUD 0030
      INTEGER ON                                                            RUD 0040
      COMMON /CONST/ PI,RAD,UO                                              RUD 0050
      COMMON /FRUD/ FX,FY,FZ,FK,FM,FN                                       RUD 0060
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,      RUD 0070
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHC          RUD 0080
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7      RUD 0090
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,      RUD 0100
     -IRUD,IPROP,IAEROD,IRHS                                                RUD 0110
      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,      RUD 0120
     ARCLB,RTC,RUDANG,TIR(25)                                               RUD 0130
      COMMON /VARBLE/ VAL(40)                                               RUD 0140
      EQUIVALENCE (VAL(1),TIME),(VAL(2),U),(VAL(3),V),(VAL(4),W),           RUD 0150
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),         RUD 0160
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),    RUD 0170
     3(VAL(24),PB)                                                          RUD 0180
      EQUIVALENCE (DELRUD(1),RUD(1)),(TIR(1),TR(1))                         RUD 0190
      DIMENSION RUD(1),TR(1)                                                RUD 0200
      EQUIVALENCE (VAL(18),FANPWR)                                          RUD 0210
      DATA ENE /1.28E-5/                                                    RUD 0220
C                                                                           RUD 0230
CC    CALCULATE PROGRAMMED RUDDER DEFLECTION                                RUD 0240
C                                                                           RUD 0250
      TL=TIME                                                               RUD 0260
      IF(NPR.EQ.0.0) GO TO 5                                                RUD 0270
      GO TO 6                                                               RUD 0280
    5 RUDANG=DELRUD(1)                                                      RUD 0290
      RUDANG=RUDANG/RAD                                                     RUD 0300
      GO TO 7                                                               RUD 0310
    6 RUDANG=FG1(TL,NPR,TR,RUD,IR)                                          RUD 0320
      RUDANG=RUDANG/RAD                                                     RUD 0330
C                                                                           RUD 0340
CC    SIDE FORCE ON RUDDER                                                  RUD 0350
C                                                                           RUD 0360
    7 DSR=Z+ZS-XR*THETA                                                     RUD 0370
      ENDFAC=(1.+DSR/(DSR+RSPAN))                                           RUD 0380
      VH=V+XR*R-ZR*P                                                        RUD 0390
      QQ=HRHO*U*U*RAREA                                                     RUD 0400
      EFFANG=RUDANG-ENDFAC*VH/U                                             RUD 0410
      FY=2.*QQ*ENDFAC*RCLB*EFFANG                                           RUD 0420
C                                                                           RUD 0430
CC    DRAG FORCE ON RUDDER                                                  RUD 0440
C                                                                           RUD 0450
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      REY=U*(RAREA/RSPAN)/ENU                                                    RUD 0460
      CFR=.427/(ALOG10(REY)-.407)**2.64                                          RUD 0470
      PI8=PI/8.                                                                  RUD 0480
      CC=2.*CFR+ PI8*RTC*RTC*(1.+G*RSPAN/(U*U))+RCLB*EFFANG*EFFANG               RUD 0490
      FX=-2.*CD*RAREA*HRHO*U*U                                                   RUD 0500
      FZ=C.                                                                      RUD 0510
      FK=-ZR*FY                                                                  RUD 0520
      FM=FX*ZR                                                                   RUD 0530
      FN=XR*FY                                                                   RUD 0540
      IF(IRUD.NE.CN) RETURN                                                      RUD 0550
                     WRITE(6,123)                                                RUD 0560
     1FX,FY,FZ,FK,FM,FN                                                          RUD 0570
C                                                                                RUD 0580
  123 FORMAT(/10X,24HRUDDER FX,FY,FZ,FK,FM,FN /6E15.4)                           RUD 0590
C                                                                                RUD 0600
      RETURN                                                                     RUD 0610
      END                                                                        RUD 0620

C                                                                                SAM 0010
      SUBROUTINE SAM                                                             SAM 0020
C                                                                                SAM 0030
      WRITE (6,10)                                                               SAM 0040
   10 FORMAT (1H1,'YOU HAVE CALLED A DUMMY SAM SUBROUTINE.'/                     SAM 0050
     110X,'CHANGE TO BHISES TO USE THE SAM SUBROUTINE.')                         SAM 0060
      RETURN                                                                     SAM 0070
      END                                                                        SAM 0080

      SUBROUTINE SIDEWL                                                          SDWL0020
C                                                                                SDWL0030
      INTEGER ON                                                                 SDWL0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                         SDWL0050
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,INT,XMI(10),YMI(7),IX,IYSDWL0060
      COMMON /CONST/ PI,RAD,UO                                                   SDWL0070
      COMMON /GEOM/    WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM              SDWL0080
     1,DELS(4,10),XCP,ZCP                                                        SDWL0090
      COMMON /GEOMSW/ XAVG(10),DS                                                SDWL0100
      COMMON /KSWTCH/ ITHRST                                                     SDWL0110
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,          SDWL0120
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO               SDWL0130
      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),           SDWL0140
     1               FNH(2),VFY(2),VFZ(2),FXV                                    SDWL0150
      COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT                                        SDWL0160
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                              SDWL0170
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,           SDWL0180
     -IRUD,IPROP,IAEROD,IRHS                                                     SDWL0190
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7           SDWL0200
      COMMON /SIDE/FX  ,FY  ,FZ  ,FK  ,FM  ,FN  ,ALSW,YSW,XLSW,CFSW,CDSWSDWL0210
     1,VAREA  ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC               SDWL0220
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      COMMON /SLOPE/WATSLP,XPWV,XLXPWV,XPWVXS                                  SDWL0230
      COMMON /VARBLE/ VAL(40)                                                  SDWL0240
      COMMON /WAVE/ ETA(4,11),AW(10),CMEGA(10),DVOLW,NWAVE,BETA,               SDWL0250
     1               FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                       SDWL0260
     2               ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR                SDWL0270
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,ABB,CBB,SBB,        SDWL0280
     1          AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),              SDWL0290
     2          AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)                           SDWL0300
     3          ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),                        SDWL0310
     4          AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),              SDWL0320
     5          AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)                           SDWL0330
     6          ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)                         SDWL0340
     7          ,BB(36),XREF,RX                                               SDWL0350
      EQUIVALENCE                (VAL(2),U),(VAL(3),V),(VAL(4),W),            SDWL0360
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),            SDWL0370
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),       SDWL0380
     3(VAL(24),PB)                                                             SDWL0390
      DIMENSION GAP(2,11),DSW(2,11)                                            SDWL0400
      DIMENSION FZHOLD(2), FZHDRP(2)                                           SDWL0410
      DATA ENU /1.28E-5/                                                       SDWL0420
C                                                                              SDWL0430
      PBAR=PB-PINF                                                             SDWL0440
      PBHEAD=PBAR/(RHO*G)                                                      SDWL0450
C                                                                              SDWL0460
C     GAP OR WETTED DRAFT CALCULATION                                          SDWL0470
C                                                                              SDWL0480
      DO 10 J=1,2                                                              SDWL0490
      N=NSTA(J)                                                                SDWL0500
      DO 10 K=1,N                                                              SDWL0510
      DD=ZS+Z+YY(J,K)*PHI-XX(1,K)*THETA+ETA(J,K)                               SDWL0520
      DDIN=DD-WATSLP*(XPWVXS-XX(J,K))                                          SDWL0530
      IF(DDIN.LT.BUBHGT) GO TO 101                                             SDWL0540
      IF ( VAL(1)-TOLD .LT. DELPNT )  GO TO 101                                SDWL0550
      TOLD = VAL(1)                                                            SDWL0560
      WRITE (6,100) XX(J,K),VAL(1),DD                                          SDWL0570
  100 FORMAT(/10X,43HWATER CONTACT WITH TOP OF BUBBLE CHAMBER AT F7.2,         SDWL0580
     -14H FT.    TIME = F7.2,19H SEC.    IMMERSION= F7.2,4H FT. )             SDWL0590
  101 CONTINUE                                                                 SDWL0600
      DSW(J,K)=(SIGN(1.,DD)+1.)*DD/2.                                          SDWL0610
      IF (DDIN) 6,8,8                                                          SDWL0620
    6 IF(DSW(J,K)-PBHEAD) 7,8,8                                                SDWL0630
    7 GAP(J,K)=-DDIN*(1.-(DSW(J,K))/PBHEAD)                                    SDWL0640
      GO TO 10                                                                 SDWL0650
    8 GAP(J,K)=0.0                                                             SDWL0660
   10 CONTINUE                                                                 SDWL0670
C                                                                              SDWL0680
C     LEAKAGE AREA                                                             SDWL0690
C
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      ALSW=0.0                                                          SDWL0710
      DO 20 J=1,2                                                       SDWL0720
      N=NSTA(J)-1                                                       SDWL0730
      DO 20 I=1,N                                                       SDWL0740
      ALSW=ALSW+(GAP(J,I)+GAP(J,I+1))*DELX/2.                           SDWL0750
   20 CONTINUE                                                          SDWL0760
C                                                                       SDWL0770
C     CROSS-FLOW DRAG ON SIDEWALLS                                      SDWL0780
C                                                                       SDWL0790
      FYD=0.0                                                           SDWL0800
      FKD=0.0                                                           SDWL0810
      FND=0.0                                                           SDWL0820
      DO 15 I=1,2                                                       SDWL0830
      N=NSTA(I)-1                                                       SDWL0840
      DO 15 J=1,N                                                       SDWL0850
      DSWAV(I,J)=(DSW(I,J)+DSW(I,J+1))/2.                               SDWL0860
      VREL      =V+XAVG(J)*R-(ZS-DSWAV(I,J)/2.)*P                       SDWL0870
      DF(I,J)=-  .5*RHO*CDSW*VREL     *ABS(VREL     )*DELX     *DSWAV(I,J)SDWL0880
      FYD=FYD+DF(I,J)                                                   SDWL0890
      FND=FND+DF(I,J)*XAVG(J)                                           SDWL0900
   15 FKD=FKD-(ZS-DSWAV(I,J)/2.)*DF(I,J)                                SDWL0910
C                                                                       SDWL0920
C     SET UP STERN LIMIT OF FORCE DETERMINATION                         SDWL0930
C                                                                       SDWL0940
      XSS = -XS                                                         SDWL0950
      GO TO 16                                                          SDWL0960
      ENTRY SIDWLM                                                      SDWL0970
      XSS = XMI(IX)                                                     SDWL0980
   16 IP=1.+(THETA*RAD-STH)/DTH                                         SDWL0990
      IP=MAXO(MINO(IP,NTH),1)                                           SDWL1000
      IP1=MINO(IP+1,NTH)                                                SDWL1010
      DTHETA=(IP-1)*DTH+STH                                             SDWL1020
      DIP= (THETA*RAD-DTHETA)/DTH                                       SDWL1030
C                                                                       SDWL1040
C     CALC REYNOLDS NO. AND DRAG COEFF.                                 SDWL1050
C                                                                       SDWL1060
      REY=U*XLSW/ENU                                                    SDWL1070
      CDT=.427/(ALOG10(REY)-.407)**2.64                                 SDWL1080
C                                                                       SDWL1090
C     SIDEWALL FORCES, P/S                                              SDWL1100
C                                                                       SDWL1110
      DO 40 J=1,2                                                       SDWL1120
      WAREA=0.0                                                         SDWL1130
      N=NSTA(J)-1                                                       SDWL1140
      NI = (XSS+XS)*N/XLSW+1.5                                          SDWL1150
      DO 21 I=NI,N                                                      SDWL1160
      ZOR1=1.                                                           SDWL1170
      IF(DSWAV(J,I).EQ. 0.0) ZOR1=0.0                                   SDWL1180
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   21  WAREA=WAREA+DELX*(2.*DSWAV(J,I)+ZCR1*AVBMSW)                          SDWL1180
       FXH(J)=-  HRHO*CDT*WAREA*U*U                                          SDWL1190
       PM1=2*J-3                                                             SDWL1200
       YLSW=PM1*YSW                                                          SDWL1210
       CS= Z    +ZS+YLSW*PHI                                                 SDWL1220
       DSS=DS-XSS*THETA                                                      SDWL1230
       ZCR1=(SIGN(1.,DSS)+1.)/2.                                             SDWL1240
       CSS=DSS*ZCR1                                                          SDWL1250
       IDSS=1.5+(DSS-SBB)/DBB                                                SDWL1260
       IDSS=MINO(NBB,IDSS)                                                   SDWL1270
       BS=BB(IDSS)                                                           SDWL1280
       ZCR1=(SIGN(1.,DSS)+1.)/2.                                             SDWL1290
       CSS=DSS*ZCR1                                                          SDWL1300
       CREOW=DSS-(XX(J,N+1)-XSS)*THETA                                       SDWL1310
       IF(DRBOW.LT.0.0) DRBOW=0.0                                            SDWL1320
       A33S=(RHO*PI*BS**2)/8.                                                SDWL1330
       A22S=(RHO*.4*PI*DSS**2)/2.                                            SDWL1340
       IF(THETA.LT.0.0) A22S=.4*RHO*PI*DRBOW*DRBOW/2.                        SDWL1350
       CSR=DS-(XREF-XS)*THETA                                                SDWL1360
       ID=1.+(DSR*12.-SDS)/DDS                                               SDWL1370
       ID=MAXO(MINO(ID,NDS),1)                                               SDWL1380
       DDSR =(ID-1)*DDS +SDS                                                 SDWL1390
       ID1=MINO(ID+1,NDS)                                                    SDWL1400
       DID= (DSR*12.-DDSR)/DDS                                               SDWL1410
       BC0=AC0( 1,ID,IP)                                                     SDWL1420
       BC00=AC00( 1,ID,IP)                                                   SDWL1430
       BC2=AC2( 1,ID,IP)                                                     SDWL1440
       BC5 = AC5(1,ID,IP)                                                    SDWL1450
       BC6 = AC6(1,ID,IP)                                                    SDWL1460
       BC0 =BC0 +DID*(AC0 (1,ID1,IP)-BC0 ) +DIP*(AC0 (1,ID,IP1)-BC0         SDWL1470
      1    +DID*(AC0 (1,ID1,IP1)-AC0 (1,ID,IP1)-AC0 (1,ID1,IP)+BC0 ))       SDWL1480
       BC0C=BC00+DID*(AC00(1,ID1,IP)-BC00) +DIP*(AC00(1,ID,IP1)-BC00         SDWL1490
      1    +DID*(AC00(1,ID1,IP1)-AC00(1,ID,IP1)-AC0C(1,ID1,IP)+BC00))       SDWL1500
       BC2 =BC2 +DID*(AC2 (1,ID1,IP)-BC2 ) +DIP*(AC2 (1,ID,IP1)-BC2         SDWL1510
      1    +DID*(AC2 (1,ID1,IP1)-AC2 (1,ID,IP1)-AC2 (1,ID1,IP)+BC2 ))       SDWL1520
       BC5 =BC5 +DID*(AC5 (1,ID1,IP)-BC5 ) +DIP*(AC5 (1,ID,IP1)-BC5         SDWL1530
      1    +DID*(AC5 (1,ID1,IP1)-AC5 (1,ID,IP1)-AC5 (1,ID1,IP)+BC5 ))       SDWL1540
       BC6 =BC6 +DID*(AC6 (1,ID1,IP)-BC6 ) +DIP*(AC6 (1,ID,IP1)-BC6         SDWL1550
      1    +DID*(AC6 (1,ID1,IP1)-AC6 (1,ID,IP1)-AC6 (1,ID1,IP)+BC6 ))       SDWL1560
C                                                                            SDWL1570
CC     SHIFT MCMENT CENTER FRCM XREF TO C.G.                                 SDWL1580
C                                                                            SDWL1590
       BCC0 = BC00-(XS-XREF)*BC0                                             SDWL1600
       BC6  = BC6 -(XS-XREF)*BC5                                             SDWL1610
C                                                                            SDWL1620
CC     HYDROSTATIC AND HYDRODYNAMIC FORCES                                   SDWL1630
C                                                                            SDWL1640
       FZH(J) =-G*BC0-U*U*A33S*THETA-U*A33S*W+Q*U*(-BC2+A33S*XSS)            SDWL1650
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     1    -U*A33S*P*YLSW                                                    SDWL1660
          FMH(J) =-U*XSS*XSS*A33S*Q+G*BC00+U*(A33S*XSS+BC2)*(W+U*THETA       SDWL1670
     1   +YLSW*P)                                                           SDWL1680
          FYH(J) =-A22S*U*(V+XSS*R  -ZS*P)                                  SDWL1690
          FNH(J) = FYH(J)*XSS-U*((V-ZS*P)*BC5+R*BC6)                        SDWL1700
C                                                                           SDWL1710
CC        ADD VERTICAL FORCE DUE TO DEADRISE PROJECTION OF LATERAL FORCE    SDWL1720
C                                                                           SDWL1730
          DDRANG=0.0                                                        SDW*1740
          IF (DS.GT.0.5833) DDRANG=(DS-0.5833)*0.0629                       SDW*1750
          DRANG=1.021+DDRANG-PM1*PHI                                        SDW*1760
          CTNDR= COTAN(DRANG)                                               SDW*1770
          RUDSIG=SIGN(1.,RUDANG)                                            SDW*1780
          IF (RUDSIG.NE.PM1) CTNDR=PM1*TAN(PHI)                             SDW*1781
          FZHOLD(J)=FZH(J)                                                  SDWL1790
          FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1                                 SDWL1800
          FZH(J)=FZH(J)+FZHDRP(J)                                           SDWL1810
          IF (IMT.EQ.2)  GO TO 40                                           SDWL1820
C                                                                           SDWL1830
CC        CALC OF FORCE ON VENTRAL FINS REMOVED                             SDWL1840
C                                                                           SDWL1850
39        CONTINUE                                                          SDWL1860
40        CONTINUE                                                          SDWL1870
          IF (IMT.EQ.2) GO TO 41                                            SDWL1880
C                                                                           SDWL1890
CC        TOTAL SIDEWALL FORCES AND MOMENTS                                 SDWL1900
C                                                                           SDWL1910
          FX=FXH(1)+FXH(2)                                                  SDWL1920
          FY=FYH(1)+FYH(2)                                                  SDWL1930
          FZ=FZH(1)+FZH(2)                                                  SDWL1940
          FK=(FZH(2)-FZH(1))*YSW           +FKD -FY*ZS                      SDWL1950
          FY=FY+FYD                                                         SDWL1960
          FM=FMH(1)+FMH(2)+ZS*FX                                            SDWL1970
          FN= FND +FNH(1)+FNH(2) +(FXH(1)-FXH(2))*YSW                       SDWL1980
C                                                                           SDWL1990
CC        DRAG FORCE ON FINS REMOVED                                        SDWL2000
C                                                                           SDWL2010
    41 CONTINUE                                                             SDWL2020
C                                                                           SDWL2030
CC        ADD ROLL DAMPING DUE TO VERTICAL WAVE GENERATION                  SDWL2040
C                                                                           SDWL2050
          DSS=Z+ZS-XSS*THETA                                                SDWL2060
          ZOR1=(SIGN(1.,DSS)+1.)/2.                                         SDWL2070
          DSS=DSS*ZOR1                                                      SDWL2080
          DS=Z+ZS                                                           SDWL2090
          DSR=DS-(XREF-XS)*THETA                                            SDWL2100
          ID=1.+(DSR*12.-SDS)/DDS                                           SDWL2110
          ID=MAXO(MINO(ID,NDS),1)                                           SDWL2120
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      DDSR=(ID-1)*DDS+SDS                                                SDWL2130
      ID1=MINO(ID+1,NDS)                                                 SDWL2140
      DID= (DSR*12.-DDSR)/DDS                                            SDWL2150
      BC2=AC2(1,ID,IP)                                                   SDWL2160
      BC2=BC2 +DID*(AC2 (1,ID1,IP)-BC2 ) +DIP*(AC2 (1,ID,IP1)-BC2       SDWL2170
     1   +DID*(AC2 (1,ID1,IP1)-AC2 (1,ID,IP1)-AC2 (1,ID1,IP)+BC2 ))     SDWL2180
      FKOLD=FK                                                           SDWL2190
      FK=FK-PROMO2*YSW*YSW*BC2*P/PI                                      SDWL2200
      FZH(1)=FZH(1)+PROMO2/2.*YSW*BC2*P/PI                               SDWL2210
      FZH(2)=FZH(2)-PROMO2/2.*YSW*BC2*P/PI                               SDWL2220
      IF(PROMO3.EQ.1.0) WRITE(6,200) VAL(1), FZHOLD(1), FZHOLD(2),       SDWL2230
     1FZHDRP(1), FZHDRP(2), FZH(1), FZH(2), FKOLD, FK                    SDWL2240
  200 FORMAT(/2X,'TIME=',1X,E15.4,2X,'OLD VERTICAL FORCES',2(5X,E15.4)/  SDWL2250
     125X,'VERTICAL DEADRISE FORCES',2(5X,E15.4)/25X,'NEW VERTICAL FORCE SDWL2260
     2S',2(5X,E15.4)/25X,'OLD AND NEW ROLL MOMENTS',2(5X,E15.4)/)        SDWL2270
      IF (ISIDWL.NE.ON) RETURN                                           SDWL2280
      DO 42 I=1,2                                                        SDWL2290
      DO 42 J=1,11                                                       SDWL2300
      GAP(I,J)=12.0*GAP(I,J)                                             SDWL2310
   42 DSW(I,J)=12.0*DSW(I,J)                                             SDWL2320
      WRITE( 6,123) ((GAP(I,J),J=1,11),I=1,2),((DSW(I,J),J=1,11),I=1,2),SDWL2330
     1 FX,FY,FZ,FK,FM,FN                                                 SDWL2340
C                                                                        SDWL2350
  123 FORMAT(/10X,8HSIDEWALL /25H GAP (FT.) (STERN TO BOW) /14H PORT SIDSDWL2360
     1EWALL /11F10.5/14H STBD SIDEWALL /11F10.5/37H IMMERSION DEPTH (FT.SDWL2370
     2) (STERN TO BOW) /14H PORT SIDEWALL /11F10.5/14H STBD SIDEWALL /   SDWL2380
     3 11F10.5/10X,26HSIDEWALL FX,FY,FZ,FK,FM,FN /6E15.4)                SDWL2390
C                                                                        SDWL2400
      RETURN                                                             SDWL2410
      END                                                                SDWL2420

C                                                                        SHX 0010
      FUNCTION SHXYAX (X,Z,ANGYAX,PI)                                    SHX 0020
C                                                                        SHX 0030
      H=SQRT(X**2+Z**2)                                                  SHX 0040
      IF(X.EQ.0.0) GO TO 1                                               SHX 0050
      ARG=Z/X                                                            SHX 0060
      ANGOLD=ATAN(ARG)                                                   SHX 0070
      IF(ANGOLD.GE.0.0) GO TO 2                                          SHX 0080
      ANGNEW=ANGOLD+PI-ANGYAX                                            SHX 0090
      GO TO 3                                                            SHX 0100
    1 ANGNEW=PI/2.0-ANGYAX                                               SHX 0110
      GO TO 3                                                            SHX 0120
    2 ANGNEW=ANGOLD-ANGYAX                                               SHX 0130
    3 SHXYAX=H*COS(ANGNEW)                                               SHX 0140
C                                                                        SHX 0150
      RETURN                                                             SHX 0160
      END                                                                SHX 0170
```

```
C                                                                               SSL 0010
      SUBROUTINE STNSL                                                          SSL 0020
C                                                                               SSL 0030
      INTEGER ON                                                                SSL 0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                        SSL 0050
      COMMON /CONST/ PI,RAD,UO                                                  SSL 0060
      COMMON /FORSS/ FX,FY,FZ,FK,FM,FN,QL,FMS                                   SSL 0070
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,SSL 0080
     11C),XCP,ZCP                                                               SSL 0090
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)SSL 0100
     1,ARM2S(10)                                                                SSL 0110
      COMMON /KSWTCH/ ITHRST                                                    SSL 0120
      COMMON /LEAKER/ ALEAK,CFSS                                                SSL 0130
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMSSL 0140
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                                 SSL 0150
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,ISSL 0160
     1RUD,IPROP,IAEROD,IRHS                                                     SSL 0170
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  SSL 0180
      COMMON/SLOPE/WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                              SSL 0190
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,CELYSS,DPSS,ELMAXS,YAVSSL 0200
     1GS(10)                                                                    SSL 0210
      COMMON /STSLR/ CPHI,CPHID                                                 SSL 0220
      COMMON /VALOLD/ YOLD(20)                                                  SSL 0230
      COMMON /VARBLE/ VAL(40)                                                   SSL 0240
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),CVCLW,NWAVE,BETA,FXWAV,FYSSL 0250
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBSSL 0260
     2BAR                                                                       SSL 0270
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VASSL 0280
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VASSL 0290
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)SSL 0300
     3, (VAL(24),PB)                                                            SSL 0310
      DIMENSION GAP(11), ELSKI(11), ELSKIL(11), AIRLEN(11), CTNSL(6,24) SSL 0320
      DATA ENU,UWSKI,CLSKI,GPS,HINGHT/1.28E-5,0.0,1.5708,.4644,1.875/   SSL 0330
      DATA CTNSL/0.0,3.8,7.0,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,C.SSL 0340
     10,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,C.0,5.2,8.9,12SSL 0350
     2.4,15.4,18.3,0.0,5.5,9.4,13.1,16.1,19.2,0.0,5.8,9.9,13.8,17.1,20.6SSL 0360
     3,C.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,1SSL 0370
     41.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,2SSL 0380
     54.1,28.3,0.0,8.2,15.3,22.1,26.3,3C.8,0.0,9.6,17.5,24.2,29.7,34.6,0SSL 0390
     6.C,11.9,20.0,25.4,32.3,38.0,0.0,14.0,23.3,30.0,35.8,41.0,0.0,17.5,SSL 0400
     725.5,32.5,39.7,44.5,0.0,21.6,30.0,38.7,42.0,47.0,0.0,24.6,33.7,41.SSL 0410
     80,45.0,48.7,0.0,28.3,38.5,45.0,48.7,48.7,0.C,35.0,45.0,48.7,48.7,4SSL 0420
     98.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,SSL 0430
     $48.7,48.7,48.7,48.7,48.7/                                                 SSL 0440
C                                                                               SSL 0450
      IF (ELMAXS.GT.HINGHT) ELMAXS=HINGHT                                       SSL 0460
      DO 1 J=1,11                                                               SSL 0470
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      GAP(J) = 0.0                                                          SSL 0480
      ELSKI(J) = 0.0                                                        SSL 0490
      ELSKIL(J) = 0.0                                                       SSL 0500
      AIRLEN(J) = 0.0                                                       SSL 0510
    1 CONTINUE                                                              SSL 0520
C                                                                           SSL 0530
CC    'EFDEP' IS THE EFFECTIVE LIFTING DEPTH OF THE STERN SEAL              SSL 0540
C                                                                           SSL 0550
      EFDEP = 6.0                                                           SSL 0560
      MM = EFDEP                                                            SSL 0570
      ALSS = 0.0                                                            SSL 0580
      FX = 0.0                                                              SSL 0590
      FZ = 0.0                                                              SSL 0600
      FK = 0.0                                                              SSL 0610
      FM = 0.0                                                              SSL 0620
      FN = 0.0                                                              SSL 0630
      AGAP1 = 0.0                                                           SSL 0640
      AGAP2 = 0.0                                                           SSL 0650
      AGAPA1 = 0.0                                                          SSL 0660
      DELP = PSS-PB                                                         SSL 0670
      IF (DELP.LT.0.0) DELP=0.0                                             SSL 0680
      PBAR = PB-PINF                                                        SSL 0690
C                                                                           SSL 0700
CC    CALCULATE ELSKI HERE.                                                 SSL 0710
C                                                                           SSL 0720
      SINDIF = SINTH-COSTH*THETA                                            SSL 0730
      CCSDIF = COSTH+SINTH*THETA                                            SSL 0740
      X1 = XSS+ZSS*THETA-XLF*SINDIF                                         SSL 0750
      Z1 = (-Z-ZSS+XSS*THETA-ELMAXS*CCS(THETA))                             SSL 0760
C                                                                           SSL 0770
CC    CALCULATE GAP HERE.                                                   SSL 0780
C                                                                           SSL 0790
      N = NSTA(4)                                                           SSL 0800
      DO 2 K=1,N                                                            SSL 0810
      ELSKI(K) = (ETA(4,K)-DETADX(K)*(XX(4,K)-X1)-Z1)+YY(4,K)*PHI           SSL 0820
     1-XPWV*WATSLP                                                          SSL 0830
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT                               SSL 0840
      ELSKIL(K) = ELSKI(K)+GPS                                              SSL 0850
      IF (ELSKIL(K).GT.HINGHT) ELSKIL(K)=HINGHT                             SSL 0860
      IF (ELSKIL(K).LT.(HINGHT-ELMAXS)) ELSKIL(K)=HINGHT-ELMAXS             SSL 0870
      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXS)                                    SSL 0880
      IF (GAP(K).LT.0.0) GAP(K)=0.0                                         SSL 0890
      MM1 = ELSKIL(K)*12.0                                                  SSL 0900
      MM2 = MM1+1                                                           SSL 0910
      MM3 = MM2+1                                                           SSL 0920
      DLINC = ELSKIL(K)*12.0-MM1                                            SSL 0930
      STNSL1 = CTNSL(MM,MM2)                                                SSL 0940
      STNSL2 = CTNSL(MM,MM3)                                                SSL 0950
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      AIRLEN(K) = ((STNSL2-STNSL1)*DLINC+STNSL1)/12.0                    SSL 0960
    2 CONTINUE                                                          SSL 0970
      N = NSTA(4)-1                                                     SSL 0980
      DO 5 J=1,N                                                        SSL 0990
      ELSKIA = (ELSKI(J+1)+ELSKI(J))/2.                                 SSL 1000
      ELSKLA = (ELSKIL(J+1)+ELSKIL(J))/2.0                              SSL 1010
      AIRLAV = (AIRLEN(J+1)+AIRLEN(J))/2.0                              SSL 1020
      AGAP = ELSKLA-ELSKIA                                              SSL 1030
      AGAP1 = AGAP                                                      SSL 1040
      IF (AGAP.LT.GPS) AGAP=GPS                                         SSL 1050
      IF (AGAP1.GT.GPS) AGAP1=GPS                                       SSL 1060
      ARM1S(J) = XX(4,J)+ELSKIA/2.                                      SSL 1070
      ARM2S(J) = ZS-ELSKIA                                              SSL 1080
      DFSS(J) = -DELP*DELYSS*AIRLAV/(GPS/AGAP)**2.0                     SSL 1090
      IF (AIRLAV.LE.0.0) GO TO 3                                        SSL 1100
      ARG = .5*RHO*U*U*AIRLAV*DELYSS                                    SSL 1110
      RESKI = U*AIRLAV/ENU                                              SSL 1120
      CDTSKI = .427/(ALOG10(RESKI)-.407)**2.64                          SSL 1130
      TSKIS(J) = -ARG*CDTSKI                                            SSL 1140
C                                                                       SSL 1150
CC    THE FOLLOWING CARD REMOVES WATER DRAG EFFECTS OF STERN SEAL       SSL 1160
C                                                                       SSL 1170
      TSKIS(J) = 0.0                                                    SSL 1180
      GO TO 4                                                           SSL 1190
    3 TSKIS(J) = 0.0                                                    SSL 1200
    4 CONTINUE                                                          SSL 1210
      FX = FX+TSKIS(J)                                                  SSL 1220
      FZ = FZ+DFSS(J)                                                   SSL 1230
      FK = FK+DFSS(J)*YAVGS(J)                                          SSL 1240
      FM = FM-DFSS(J)*ARM1S(J)+TSKIS(J)*ARM2S(J)                        SSL 1250
      FN = FN-TSKIS(J)*YAVGS(J)                                         SSL 1260
      ALSS = ALSS+(GAP(J)+GAP(J+1))*DELYSS/2.0                          SSL 1270
      AGAP2 = AGAP2+AGAP1                                               SSL 1280
      AGAPA1 = AGAP2/J                                                  SSL 1290
    5 CONTINUE                                                          SSL 1300
      ALSS = ALSS+ALEAK*(AGAPA1/GPS)                                    SSL 1310
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)                                 SSL 1320
      CL = CFSS*ALSS*SQFAC*SIGN(1.,PBAR)                                SSL 1330
      IF (ISTNSL.NE.ON) RETURN                                          SSL 1340
      WRITE (6,6) GAP,AIRLEN,FX,FY,FZ,FK,FM,FN                          SSL 1350
C                                                                       SSL 1360
    6 FORMAT (//12H  STERN SEAL/26H  GAP (FT.) PORT TO STBD. /11E11.3/28SSSL 1370
     1H  AIRLEN(FT.) PORT TO STBD. /11E11.3/10X,23HSTNSL FX,FY,FZ,FK,FM,SSL 1380
     2FN/6E15.4)                                                        SSL 1390
C                                                                       SSL 1400
      RETURN                                                            SSL 1410
      END                                                               SSL 1420
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C                                                                       T1   0010
      FUNCTION T1(X)                                                    T1   0020
C                                                                       T1   0030
      IF(ABS(X)-.1) 10,10,20                                            T1   0040
 10   T1=X*(1.-X*X/10.0)/3.                                             T1   0050
      RETURN                                                            T1   0060
 20   T1=(SIN(X)-X*COS(X))/(X*X)                                        T1   0070
      RETURN                                                            T1   0080
      END                                                               T1   0090

C                                                                       T2   0010
      FUNCTION T2(X)                                                    T2   0020
C                                                                       T2   0030
      IF(ABS(X)-.1) 10,10,20                                            T2   0040
10    T2=1.-X*X/6.                                                      T2   0050
      RETURN                                                            T2   0060
20    T2=SIN(X)/X                                                       T2   0070
      RETURN                                                            T2   0080
      END                                                               T2   0090

C                                                                       WAVS0010
      SUBROUTINE WAVES(TIME)                                            WAVS0020
C                                                                       WAVS0030
      INTEGER ON                                                        WAVS0040
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IYWAVS0050
      COMMON /CONST/ PI,RAD,UO                                          WAVS0060
      COMMON /GEOM/    WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VCLNOM     WAVS0070
     1,CELS(4,10),XCP,ZCP                                               WAVS0080
      COMMON /GEOMBS/DETABX(11),DETABT(11),ARM1B(10),ARM2B(10)          WAVS0090
     1 ,CFBS(10),TSKIB(10)                                              WAVS0100
      COMMON /GEOMSS/DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10) WAVS0110
     1 ,ARM2S(10)                                                       WAVS0120
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,  WAVS0130
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO      WAVS0140
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)          WAVS0150
      COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT                               WAVS0160
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,  WAVS0170
     -IRUD,IPROP,IAEROD,IRHS                                            WAVS0180
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  WAVS0190
      COMMON /RISER/ AMPTC                                              WAVS0200
      COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWWAVS0210
     1,VAREA  ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC      WAVS0220
      COMMON /VARBLE/ VAL(40)                                           WAVS0230
      COMMON /WAVE/ ETA(4,11),AW(10),CMEGA(10),DVCLW,NWAVE,BETA,        WAVS0240
     1               FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                WAVS0250
     2               ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR         WAVS0260
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DCS,SDS,NTH,DTH,STH,NBB,DBB,SEB,  WAVS0270
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     1           AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),          WAVS0280
     2           AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)                       WAVS0290
     3           ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),                    WAVS0300
     4           AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),          WAVS0310
     5           AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)                       WAVS0320
     6           ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)                     WAVS0330
     7           ,BB(36),XREF,RX                                           WAVS0340
      DIMENSION WC0(2),WC00(2),WC1(2),WC2(2),WC3(2),WC4(2),WC5(2),WC6(2)WAVS0350
     1          ,WC7(2),WC8(2)                                             WAVS0360
      DIMENSION WS0(2),WS00(2),WS1(2),WS2(2),WS3(2),WS4(2),WS5(2),WS6(2)WAVS0370
     1          ,WS7(2),WS8(2)                                             WAVS0380
      EQUIVALENCE                (VAL(2),U),(VAL(3),V),(VAL(4),W),       WAVS0390
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),        WAVS0400
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),WAVS0410
     3(VAL(24),PB)                                                         WAVS0420
      EQUIVALENCE (VAL(16),ETACG)                                          WAVS0430
C                                                                          WAVS0440
      IF (NWAVE.EQ.0) RETURN                                               WAVS0450
C                                                                          WAVS0460
CC    CALCULATION OF SHIFT OF XCPO                                         WAVS0470
C                                                                          WAVS0480
      XCPO=XCP+0.001975*(U*0.5921-30.0)**2-0.974                           WAVS0490
      XCPC=SHXYAX(XCPO,ZCP,THETA,PI)                                       WAVS0500
      GAMMA=BETA-PSI                                                       WAVS0510
      SIGAM=SIN(GAMMA)                                                     WAVS0520
      COGAM=COS(GAMMA)                                                     WAVS0530
      FC= -X*COSBET -Y*SINBET                                              WAVS0540
      DVCLW=0.0                                                            WAVS0550
      ETACG=0.0                                                            WAVS0560
      N=NSTA(3)                                                            WAVS0570
      DO 1 J=1,N                                                           WAVS0580
      DETABX(J)=0.0                                                        WAVS0590
    1 CONTINUE                                                             WAVS0600
      N=NSTA(4)                                                            WAVS0610
      DO 2 J=1,N                                                           WAVS0620
      DETADX(J)=0.0                                                        WAVS0630
    2 CONTINUE                                                             WAVS0640
      DO 10 J=1,4                                                          WAVS0650
      N=NSTA(J)                                                            WAVS0660
      DO 10 K=1,N                                                          WAVS0670
   10 ETA(J,K)=0.0                                                         WAVS0680
      DO 15 J=1,2                                                          WAVS0690
      FXW(J) = 0.0                                                         WAVS0700
      FYW(J) = 0.0                                                         WAVS0710
      FZW(J) = 0.0                                                         WAVS0720
      FKW(J) = 0.0                                                         WAVS0730
      FMW(J) = 0.0                                                         WAVS0740
      FNW(J) = 0.0                                                         WAVS0750
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   15 CONTINUE                                                          WAVS0760
      XSS = -XS                                                         WAVS0770
      IF (IMT.EQ.2)  XSS = XMI(IX)                                      WAVS0780
      IP = 1  +(THEBAR*RAD-STH)/DTH                                     WAVS0790
      IP=MAXO(MINO(IP,NTH),1)                                           WAVS0800
      IP1=MINO(IP+1,NTH)                                                WAVS0810
      DTHETA=(IP-1)*DTH+STH                                             WAVS0820
      DIP= (THETA*RAD-DTHETA)/DTH                                       WAVS0830
C     TIME RISE FACTOR FOR WAVE AMPLITUDE                               WAVS0840
      AMPFAC=1.-EXP(-TIME/AMPTC)                                        WAVS0850
      DO 100 I=1,NWAVE                                                  WAVS0860
      CM1=OMEGA(I)                                                      WAVS0870
      CM2=CM1*OM1                                                       WAVS0880
      XWK=CM2/G                                                         WAVS0890
      AA=AW(I)*AMPFAC                                                   WAVS0900
      FT= CM1*TIME+XWK*FO                                               WAVS0910
      AL=XWK*COGAM                                                      WAVS0920
      IAA= 1+(ABS(AL)-SAL)/DAL                                          WAVS0930
      IAA=MAXO(MINO(IAA,NAL),1)                                         WAVS0940
      IAA1=MINO(IAA+1,NAL)                                              WAVS0950
      DAA= (IAA-1)*DAL+SAL                                              WAVS0960
      DIA= (ABS(AL)-DAA)/DAL                                            WAVS0970
      SALP=SIGN(1.,AL)                                                  WAVS0980
C                                                                       WAVS0990
CC    WAVE FORCES AND MOMENTS ON THE SIDEWALLS                          WAVS1000
C                                                                       WAVS1010
      DO 40 J=1,2                                                       WAVS1020
      YLSW=(2*J-3)*YSW                                                  WAVS1030
      WE=FT+XWK*SIGAM*YLSW                                              WAVS1040
      ST=SIN(WE)                                                        WAVS1050
      CT=COS(WE)                                                        WAVS1060
      DS= ZBAR+ZS+YLSW*PHIBAR                                           WAVS1070
      DSR=DS-(XREF-XS)*THEBAR                                           WAVS1080
      ID=1.+(DSR*12.-SDS)/DDS                                           WAVS1090
      ID=MAXO(MINO(ID,NDS),1)                                           WAVS1100
      DDSR =(ID-1)*DDS +SDS                                             WAVS1110
      DID= (DSR*12.-DDSR)/DDS                                           WAVS1120
      ID1=MINO(ID+1,NDS)                                                WAVS1130
      DSS=DS-XSS*THEBAR                                                 WAVS1140
      ZOR1=(SIGN(1.,DSS)+1.)/2.                                         WAVS1150
      DSS=DSS*ZOR1                                                      WAVS1160
      IDSS=1.5+(DSS-SBB)/DBB                                            WAVS1170
      IDSS=MINO(NBB,IDSS)                                               WAVS1180
      BS=BB(IDSS)                                                       WAVS1190
      CK = COS(XWK*COGAM*XSS)                                           WAVS1200
      A33S=(RHO*PI*BS**2)/8.                                            WAVS1210
      SK = SIN(XWK*COGAM*XSS)                                           WAVS1220
      A22S=(RHO*.4*PI*DSS**2)/2.                                        WAVS1230
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      A42S=0.0                                                                  WAVS1240
C                                                                               WAVS1250
CC    INTERPOLATION OF WAVE TABLES                                              WAVS1260
C                                                                               WAVS1270
      K=1                                                                       WAVS1280
      L=IAA                                                                     WAVS1290
41    CONTINUE                                                                  WAVS1300
      BCC=AC0( L,ID,IP)                                                         WAVS1310
      BCOC=AC00( L,ID,IP)                                                       WAVS1320
      BC1=AC1( L,ID,IP)                                                         WAVS1330
      BC2=AC2( L,ID,IP)                                                         WAVS1340
      BC3=AC3( L,ID,IP)                                                         WAVS1350
      BC4=AC4( L,ID,IP)                                                         WAVS1360
      BC5=AC5( L,ID,IP)                                                         WAVS1370
      BC6=AC6( L,ID,IP)                                                         WAVS1380
      BC7=AC7( L,ID,IP)                                                         WAVS1390
      BC8=AC8( L,ID,IP)                                                         WAVS1400
      BSC=AS0( L,ID,IP)                                                         WAVS1410
      BSCC=AS00( L,ID,IP)                                                       WAVS1420
      BS1=AS1( L,ID,IP)                                                         WAVS1430
      BS2=AS2( L,ID,IP)                                                         WAVS1440
      BS3=AS3( L,ID,IP)                                                         WAVS1450
      BS4=AS4( L,ID,IP)                                                         WAVS1460
      BS5=AS5( L,ID,IP)                                                         WAVS1470
      BS6=AS6( L,ID,IP)                                                         WAVS1480
      BS7=AS7( L,ID,IP)                                                         WAVS1490
      BS8=AS8( L,ID,IP)                                                         WAVS1500
      WC0 (K)=BC0 +DID*(AC0 (L,ID1,IP)-BC0 ) +DIP*(AC0 (L,ID,IP1)-BC0           WAVS1510
     1    +DID*(AC0 (L,ID1,IP1)-AC0 (L,ID,IP1)-AC0 (L,ID1,IP)+BC0 ))           WAVS1520
      WC00(K)=BC00+DID*(AC00(L,ID1,IP)-BC00) +DIP*(AC00(L,ID,IP1)-BC00          WAVS1530
     1    +DID*(AC00(L,ID1,IP1)-AC00(L,ID,IP1)-AC00(L,ID1,IP)+BC00))           WAVS1540
      WC1 (K)=BC1 +DID*(AC1 (L,ID1,IP)-BC1 ) +DIP*(AC1 (L,ID,IP1)-BC1           WAVS1550
     1    +DID*(AC1 (L,ID1,IP1)-AC1 (L,ID,IP1)-AC1 (L,ID1,IP)+BC1 ))           WAVS1560
      WC2 (K)=BC2 +DID*(AC2 (L,ID1,IP)-BC2 ) +DIP*(AC2 (L,ID,IP1)-BC2           WAVS1570
     1    +DID*(AC2 (L,ID1,IP1)-AC2 (L,ID,IP1)-AC2 (L,ID1,IP)+BC2 ))           WAVS1580
      WC3 (K)=BC3 +DID*(AC3 (L,ID1,IP)-BC3 ) +DIP*(AC3 (L,ID,IP1)-BC3           WAVS1590
     1    +DID*(AC3 (L,ID1,IP1)-AC3 (L,ID,IP1)-AC3 (L,ID1,IP)+BC3 ))           WAVS1600
      WC4 (K)=BC4 +DID*(AC4 (L,ID1,IP)-BC4 ) +DIP*(AC4 (L,ID,IP1)-BC4           WAVS1610
     1    +DID*(AC4 (L,ID1,IP1)-AC4 (L,ID,IP1)-AC4 (L,ID1,IP)+BC4 ))           WAVS1620
      WC5 (K)=BC5 +DID*(AC5 (L,ID1,IP)-BC5 ) +DIP*(AC5 (L,ID,IP1)-BC5           WAVS1630
     1    +DID*(AC5 (L,ID1,IP1)-AC5 (L,ID,IP1)-AC5 (L,ID1,IP)+BC5 ))           WAVS1640
      WC6 (K)=BC6 +DID*(AC6 (L,ID1,IP)-BC6 ) +DIP*(AC6 (L,ID,IP1)-BC6           WAVS1650
     1    +DID*(AC6 (L,ID1,IP1)-AC6 (L,ID,IP1)-AC6 (L,ID1,IP)+BC6 ))           WAVS1660
      WC7 (K)=BC7 +DID*(AC7 (L,ID1,IP)-BC7 ) +DIP*(AC7 (L,ID,IP1)-BC7           WAVS1670
     1    +DID*(AC7 (L,ID1,IP1)-AC7 (L,ID,IP1)-AC7 (L,ID1,IP)+BC7 ))           WAVS1680
      WC8 (K)=BC8 +DID*(AC8 (L,ID1,IP)-BC8 ) +DIP*(AC8 (L,ID,IP1)-BC8           WAVS1690
     1    +DID*(AC8 (L,ID1,IP1)-AC8 (L,ID,IP1)-AC8 (L,ID1,IP)+BC8 ))           WAVS1700
      WS0 (K)=BS0 +DID*(AS0 (L,ID1,IP)-BS0 ) +DIP*(AS0 (L,ID,IP1)-BS0           WAVS1710
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```
     1    +DID*(AS0 (L,ID1,IP1)-AS0 (L,ID,IP1)-AS0 (L,ID1,IP)+BS0 ))      WAVS1720
      WS00(K)=BS00+DID*(AS00(L,ID1,IP)-BS00) +DIP*(AS00(L,ID,IP1)-BS00   WAVS1730
     1    +DID*(AS00(L,ID1,IP1)-AS00(L,ID,IP1)-AS0C(L,ID1,IP)+BS00))     WAVS1740
      WS1 (K)=BS1 +DID*(AS1 (L,ID1,IP)-BS1 ) +DIP*(AS1 (L,ID,IP1)-BS1    WAVS1750
     1    +DID*(AS1 (L,ID1,IP1)-AS1 (L,ID,IP1)-AS1 (L,ID1,IP)+BS1 ))     WAVS1760
      WS2 (K)=BS2 +DID*(AS2 (L,ID1,IP)-BS2 ) +DIP*(AS2 (L,ID,IP1)-BS2    WAVS1770
     1    +DID*(AS2 (L,ID1,IP1)-AS2 (L,ID,IP1)-AS2 (L,ID1,IP)+BS2 ))     WAVS1780
      WS3 (K)=BS3 +DID*(AS3 (L,ID1,IP)-BS3 ) +DIP*(AS3 (L,ID,IP1)-BS3    WAVS1790
     1    +DID*(AS3 (L,ID1,IP1)-AS3 (L,ID,IP1)-AS3 (L,ID1,IP)+BS3 ))     WAVS1800
      WS4 (K)=BS4 +DID*(AS4 (L,ID1,IP)-BS4 ) +DIP*(AS4 (L,ID,IP1)-BS4    WAVS1810
     1    +DID*(AS4 (L,ID1,IP1)-AS4 (L,ID,IP1)-AS4 (L,ID1,IP)+BS4 ))     WAVS1820
      WS5 (K)=BS5 +DID*(AS5 (L,ID1,IP)-BS5 ) +DIP*(AS5 (L,ID,IP1)-BS5    WAVS1830
     1    +DID*(AS5 (L,ID1,IP1)-AS5 (L,ID,IP1)-AS5 (L,ID1,IP)+BS5 ))     WAVS1840
      WS6 (K)=BS6 +DID*(AS6 (L,ID1,IP)-BS6 ) +DIP*(AS6 (L,ID,IP1)-BS6    WAVS1850
     1    +DID*(AS6 (L,ID1,IP1)-AS6 (L,ID,IP1)-AS6 (L,ID1,IP)+BS6 ))     WAVS1860
      WS7 (K)=BS7 +DID*(AS7 (L,ID1,IP)-BS7 ) +DIP*(AS7 (L,ID,IP1)-BS7    WAVS1870
     1    +DID*(AS7 (L,ID1,IP1)-AS7 (L,ID,IP1)-AS7 (L,ID1,IP)+BS7 ))     WAVS1880
      WS8 (K)=BS8 +DID*(AS8 (L,ID1,IP)-BS8 ) +DIP*(AS8 (L,ID,IP1)-BS8    WAVS1890
     1    +DID*(AS8 (L,ID1,IP1)-AS8 (L,ID,IP1)-AS8 (L,ID1,IP)+BS8 ))     WAVS1900
      IF(K .EQ. 2) GOTO 42                                               WAVS1910
      K=2                                                                WAVS1920
      L =IAA1                                                            WAVS1930
      GOTO 41                                                            WAVS1940
42    BCC = WC0 (1)+DIA*(WC0 (2)-WC0 (1))                                WAVS1950
      BCC0= WC00(1)+DIA*(WC00(2)-WC00(1))                                WAVS1960
      BC1 = WC1 (1)+DIA*(WC1 (2)-WC1 (1))                                WAVS1970
      BC2 = WC2 (1)+DIA*(WC2 (2)-WC2 (1))                                WAVS1980
      BC3 = WC3 (1)+DIA*(WC3 (2)-WC3 (1))                                WAVS1990
      BC4 = WC4 (1)+DIA*(WC4 (2)-WC4 (1))                                WAVS2000
      BC5 = WC5 (1)+DIA*(WC5 (2)-WC5 (1))                                WAVS2010
      BC6 = WC6 (1)+DIA*(WC6 (2)-WC6 (1))                                WAVS2020
      BC7 = WC7 (1)+DIA*(WC7 (2)-WC7 (1))                                WAVS2030
      BC8 = WC8 (1)+DIA*(WC8 (2)-WC8 (1))                                WAVS2040
      BS0 =(WS0 (1)+DIA*(WS0 (2)-WS0 (1)))*SALP                          WAVS2050
      BS00=(WS00(1)+DIA*(WS00(2)-WS00(1)))*SALP                          WAVS2060
      BS1 =(WS1 (1)+DIA*(WS1 (2)-WS1 (1)))*SALP                          WAVS2070
      BS2 =(WS2 (1)+DIA*(WS2 (2)-WS2 (1)))*SALP                          WAVS2080
      BS3 =(WS3 (1)+DIA*(WS3 (2)-WS3 (1)))*SALP                          WAVS2090
      BS4 =(WS4 (1)+DIA*(WS4 (2)-WS4 (1)))*SALP                          WAVS2100
      BS5 =(WS5 (1)+DIA*(WS5 (2)-WS5 (1)))*SALP                          WAVS2110
      BS6 =(WS6 (1)+DIA*(WS6 (2)-WS6 (1)))*SALP                          WAVS2120
      BS7 =(WS7 (1)+DIA*(WS7 (2)-WS7 (1)))*SALP                          WAVS2130
      BS8 =(WS8 (1)+DIA*(WS8 (2)-WS8 (1)))*SALP                          WAVS2140
C                                                                        WAVS2150
CC    SHIFT MOMENT CENTER FROM XREF TO C.G.                              WAVS2160
C                                                                        WAVS2170
      BCC0 = BC00-(XS-XREF)*BC0                                          WAVS2180
      BC3  = BC3 -(XS-XREF)*BC1                                          WAVS2190
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      BC4   = BC4  -(XS-XREF)*BC2                                                WAVS2200
      BC6   = BC6  -(XS-XREF)*BC5                                                WAVS2210
      BSCO  = BSOO-(XS-XREF)*BSO                                                 WAVS2220
      BS3   = BS3  -(XS-XREF)*BS1                                                WAVS2230
      BS4   = BS4  -(XS-XREF)*BS2                                                WAVS2240
      BS6   = BS6  -(XS-XREF)*BS5                                                WAVS2250
C                                                                                WAVS2260
C     CALCULATE WAVE FORCES AND MCMENTS                                          WAVS2270
C                                                                                WAVS2280
      FZC= BS1-XWK*G*(BS2+BSO)-U*OM1*(-A33S*CK-AL*BS2)                           WAVS2290
      FZS= BC1-XWK*G*(BC2+BCO)+U*OM1*(-A33S*SK+AL*BC2)                           WAVS2300
      FMC= BS3-XWK*G*(BS4+BSOO)-U*OM1*(-A33S*XSS*CK-BC2-AL*BS4)                  WAVS2310
      FMS= BC3-XWK*G*(BC4+BCOO)+U*OM1*(-A33S*XSS*SK-BS2+AL*BC4)                  WAVS2320
      FYC= XWK*G*(BC5+BCO)-U*OM1*(-A22S*SK+AL*BC5)                               WAVS2330
      FYS= -XWK*G*(BS5+BSO)-U*OM1*(-A22S*CK-AL*BS5)                              WAVS2340
      FNC= XWK*G*(BC6+BCOO)-U*OM1*(-A22S*XSS*SK-BS5+AL*BC6)                      WAVS2350
      FNS= -XWK*G*(BS6+BSOO)-U*OM1*(-A22S*XSS*CK-BC5-AL*BS6)                     WAVS2360
      FKC=XWK*G*(BC7-BC8)+U*OM1*(-A42S*SK+AL*BC8)                                WAVS2370
      FKS= -XWK*G*(BS7-BS8)+U*OM1*(-A42S*CK-AL*BS8)                              WAVS2380
      FZW(J)=FZW(J)-AA*(FZC*CT+FZS*ST)                                           WAVS2390
      FMW(J)=FMW(J)+AA*(FMC*CT+FMS*ST)                                           WAVS2400
      FYW(J)=FYW(J)-AA*(FYC*CT+FYS*ST)*SIGAM                                     WAVS2410
      FNW(J)=FNW(J)-AA*(FNC*CT+FNS*ST)*SIGAM                                     WAVS2420
      FKW(J)=FKW(J)-AA*(FKC*CT+FKS*ST)*SIGAM                                     WAVS2430
      FXW(J)= FXW(J)-2.*AA*RHO*G*BS*DSS*SK*CT                                    WAVS2440
   40 CONTINUE                                                                   WAVS2450
      IF (IMT.EQ.2)  GO TO 100                                                   WAVS2460
C                                                                                WAVS2470
C     WAVE ELEVATION AROUND THE SIDEWALLS AND SEALS                              WAVS2480
C                                                                                WAVS2490
      DO 20 J=1,4                                                                WAVS2500
      N=NSTA(J)                                                                  WAVS2510
      DO 20 K=1,N                                                                WAVS2520
      ETA(J,K)=ETA(J,K)+SIN(XWK*(- XX(J,K)*COGAM-YY(J,K)*SIGAM)+FT)*AA           WAVS2530
20    CONTINUE                                                                   WAVS2540
      ETACG=ETACG+AA*SIN(FT)                                                     WAVS2550
      N=NSTA(3)                                                                  WAVS2560
      DO 25 J=1,N                                                                WAVS2570
      ARG=AA*COS(XWK*(-XX(3,J)*COGAM)+FT)                                        WAVS2580
      DETABX(J)=DETABX(J)-XWK*COGAM*ARG                                          WAVS2590
   25 CONTINUE                                                                   WAVS2600
      N=NSTA(4)                                                                  WAVS2610
      DO 30 J=1,N                                                                WAVS2620
      ARG=AA*COS(XWK*(-XX(4,J)*COGAM)+FT)                                        WAVS2630
      DETADX(J)=DETADX(J)-XWK*COGAM*ARG                                          WAVS2640
   30 CONTINUE                                                                   WAVS2650
C                                                                                WAVS2660
C     WAVE PUMPING                                                               WAVS2670
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C                                                                       WAVS2680
      X1=XWK*XLBW*COGAM/2.                                              WAVS2690
      X2=XWK*XBBW*SIGAM/2.                                              WAVS2700
      FTT=FT-XWK*XCPC*COGAM                                             WAVS2710
      DVCLW=DVOLW+AA*ABW*T2(X1)*T2(X2)*SIN(FTT)                         WAVS2720
100   CONTINUE                                                          WAVS2730
      IF (IMT.EQ.2)  RETURN                                             WAVS2740
C                                                                       WAVS2750
C     TOTAL WAVE FORCES AND MOMENTS                                     WAVS2760
C                                                                       WAVS2770
      FXWAV=FXW(1)+FXW(2)                                               WAVS2780
      FYWAV=FYW(1)+FYW(2)                                               WAVS2790
      FZWAV=FZW(1)+FZW(2)                                               WAVS2800
      FKWAV=FKW(1)+FKW(2)+(FZW(2)-FZW(1))*YSW      +FYWAV*ZBAR          WAVS2810
      FMWAV=FMW(1)+FMW(2)-FXWAV*ZBAR                                    WAVS2820
      FNWAV=FNW(1)+FNW(2)+(FXW(1)-FXW(2))*YSW                           WAVS2830
      IF (IWAVES.NE.ON) RETURN                                          WAVS2840
                  WRITE(6,200) ((ETA(I,J),J=1,11),I=1,4),ETACG,DVOLW    WAVS2850
     1,FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                              WAVS2860
C                                                                       WAVS2870
  200 FORMAT(/10X,5HWAVES /63H WAVE ELEVATIONS AT CRAFT STATIONS RELATIVWAVS2880
     1E TO CALM WATER (FT.) /14H PORT SIDEWALL /11F10.5/14H STBD SIDEWALWAVS2890
     2L /11F10.5/9H BOW SEAL /11F10.5/11H STERN SEAL /11F10.5/25H WAVE EWAVS2900
     3LEVATION AT C.G. = F10.5,10X,43HPLENUM VOLUME LOST DUE TO WAVES (CWAVS2910
     4U. FT.) = F15.5/10X,23HWAVES FX,FY,FZ,FK,FM,FN /6E15.4)           WAVS2920
C                                                                       WAVS2930
      RETURN                                                            WAVS2940
      END                                                               WAVS2950
```

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